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A NOVEL PIECE OF BRIDGE CONSTRUCTION AT LAWRENCE, MASS.

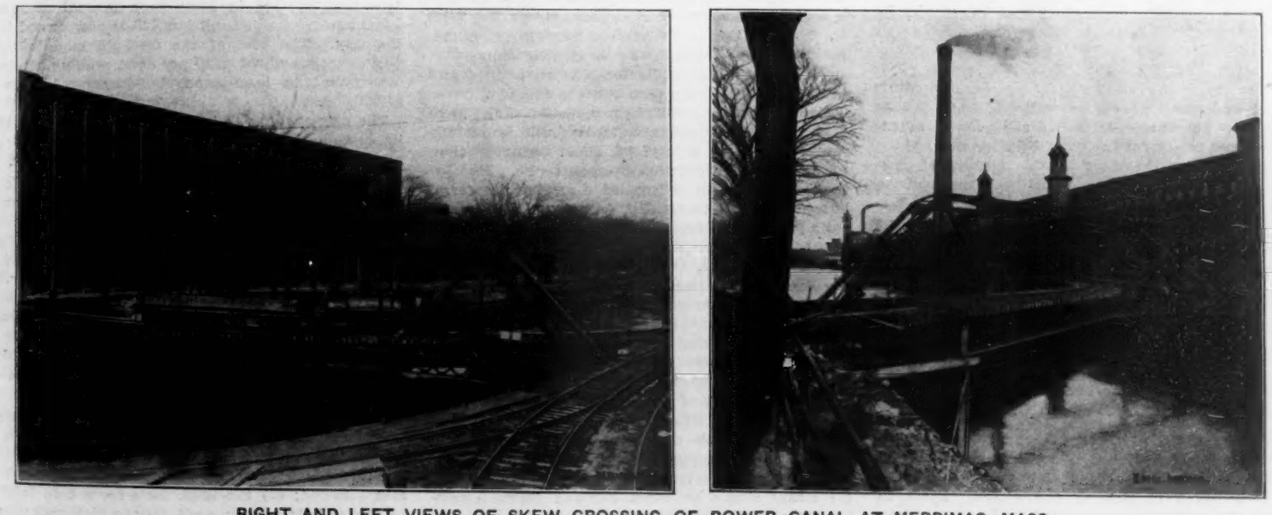
By M. F. Brown,* Assoc. M. Am. Soc. C. E.

A somewhat novel method of solving the problem of a skew crossing is furnished by a small bridge recently constructed at Lawrence, Mass. The Pacific Mills Corporation of Lawrence, with their mills located on the right-hand bank of the North Canal of the Essex Co., built during 1902 a storehouse upon the left bank of the canal. It was desired so to connect the storehouse with the packing house (upon the opposite bank) that the transportation of goods from one to the other might be made with the greatest economy and facility and at the same time with as little expenditure as possible for new equipment. A number of plans involving an elevated structure were worked out and rejected as representing too great a first cost, and the plan of connecting the two buildings with a spur track at the street grade was hit upon and adopted. This plan involved a bridge across the canal, which bridge is the subject of the present article.

The conditions involved are shown in the accompanying general plan (Fig. 1). A double-track railway runs along the right bank of the canal and close to the mill buildings and just in front of the loading platform of the packing house. It was decided, then, to run a spur from this track across the canal to the new storehouse. The existing tracks are so close to the canal as to prevent a curve being put in on the shore so as to allow the spur track to run across the canal at right angles. Consequently, the crossing had to be made either on a long skew or a curve. As the Essex Co. could not allow any supports to be put in the canal, on account of navigation, the skew crossing was impracticable, and the curve was chosen by necessity, and to make the structure as short as possible the curve was made as sharp as deemed advisable, 120 ft. radius. The grade of the base of rail being fixed by the existing tracks, and the grade of the lowest iron being fixed by the Essex Co., the problem was further complicated, inasmuch as the difference between these two grades was only 5.86 ft. The width of the canal is about 99 ft. clear between walls.

The problem presented to the writer (who as Chief Engineer of the Boston Bridge Works had the matter in charge) was, then, to design an economical structure to carry a railroad track on a curve of 120-ft. radius across a canal 99 ft. wide and to limit the depth base of rail to lower iron to 5.86 ft., and not to obstruct the waterway.

*Chief Engineer, Boston Bridge Works, Boston, Mass.



RIGHT AND LEFT VIEWS OF SKEW CROSSING OF POWER CANAL AT MERRIMAC, MASS.

The most simple solution of the problem was to make a skew bridge of sufficient clear width to allow for the curvature (inasmuch as a skew span of deck construction was not practicable on account of lack of depth). This scheme would have meant a span of about 136 ft. and 40 ft. clear width, and was considered too expensive. The next solution was to put in a single girder spanning the canal at right angles and serving to support the ends of track girders arranged parallel to the chords of the bisected curve. The objection to such a design was the difficulty of bracing the girders laterally, so a design consisting of two braced girders at right angles to the canal and supporting the ends of track girders was decided upon and worked out. The two long girders proved to be very heavy (53,000 lbs. each) for so short a span and light load (55T locomotive + 2 cars at 40,000 lbs.), and furthermore, the shallow depth (4 ft. 7½ ins. b. to b. angles) meant a very considerable deflection, so this design was in turn thrown over.

The only thing left seemed to be to provide some support from above for the ends of the track girders, but any design of arch with suspender rods seemed cumbersome and expensive, so the writer determined to try the use of trusses in place of girders for the track girder supports, and by leaving out the web members in one panel of each truss, allow the engine and cars to pass through the sides of the trusses. This design would depend upon the chords of the trusses acting as girder to transfer the shear across the panel with the missing web members. Upon working out the design, the writer was surprised to find a resulting saving of 41% in the weight of the two trusses over the girders, or a total of about 44,000 lbs. The two trusses themselves weighed 62,000 lbs., or with the bracing connecting same, a total of 72,400 lbs. This, at a cost of 5 cts. per lb. erected in place, would be $3,620 as the cost of the supporting framework which takes the place of piers.

In designing the trusses the bottom chord was made so deep as to justify the assumption that it carried all the shear across the open panel, though the top chord was made a little heavier than the direct stresses would call for. In obtaining the stresses in the trusses assumptions were made

that the bottom chord was jointed in the middle of the open panel so as not to take any moment, and also jointed at the second panel point each side of the open panel; that is, the joints were assumed as in the following sketch, Fig. 2.

These assumptions permitted the stresses being readily calculated and the members proportioned. As a matter of fact, the bridge as constructed did not have any joints in it, the bottom chord being unbroken except for the necessary splices, and no

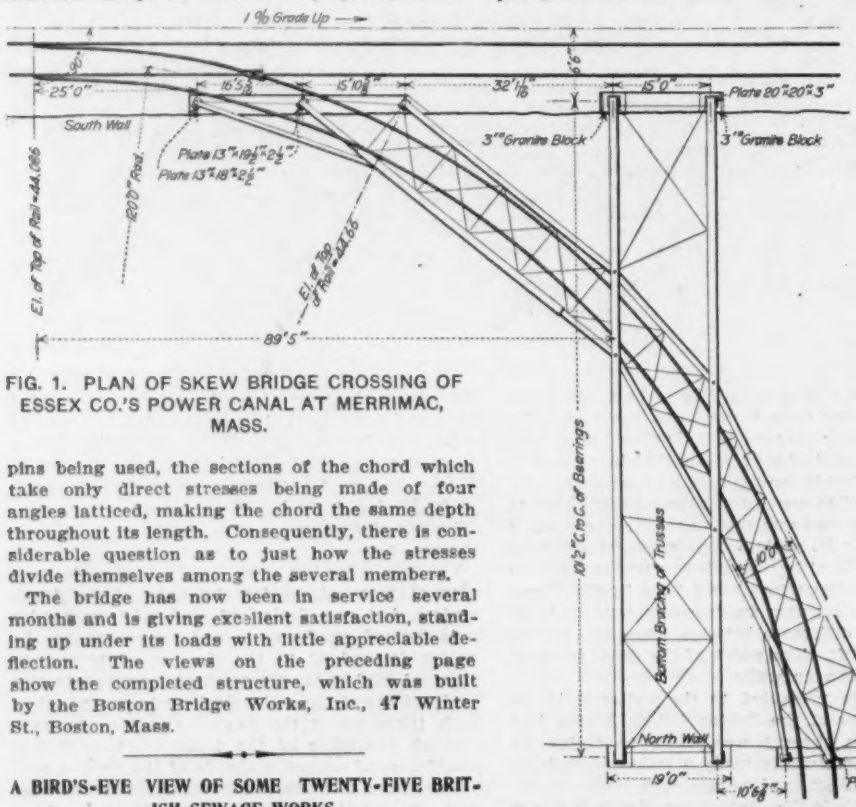


FIG. 1. PLAN OF SKEW BRIDGE CROSSING OF ESSEX CO.'S POWER CANAL AT MERRIMAC, MASS.

pins being used, the sections of the chord which take only direct stresses being made of four angles latticed, making the chord the same depth throughout its length. Consequently, there is considerable question as to just how the stresses divide themselves among the several members.

The bridge has now been in service several months and is giving excellent satisfaction, standing up under its loads with little appreciable deflection. The views on the preceding page show the completed structure, which was built by the Boston Bridge Works, Inc., 47 Winter St., Boston, Mass.

A BIRD'S-EYE VIEW OF SOME TWENTY-FIVE BRITISH SEWAGE WORKS.

(Editorial Correspondence.)

I have now visited about twenty-five works for the treatment of sewage. These works are fairly well distributed over England and the South of Scotland. They include all of the largest cities and towns in the country and a number of medium sized and small places as well. If they can be regarded as representative of the present status of sewage treatment in Great Britain, and I think they can, then the most notable feature of sewage disposal here is the diversity of methods in use or proposed.

In order that the readers of Engineering News may form their own conclusions regarding the status of sewage disposal in Great Britain, as reflected by the character of a considerable number of works, I have briefly summarized my notes on the various works which I have seen. I have not attempted to classify the works, except in order of population of the cities and towns represented. Following the summaries or outline descriptions may be found some brief general comments suggested thereby.

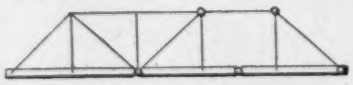


Fig. 2. Sketch Showing Location of Hinges in Bottom Chords Assumed in Calculation.

LONDON (4,536,541).—The sewage of the whole administrative County of London, amounting to some 230,000,000 gallons a day, is treated by chemical precipitation at the ends of the two outfalls at Barking and Crossness. The sludge is conveyed to sea by means of six large vessels. After a long series of experiments begun under the direction of Mr. W. J. Dibden, formerly Chemist to the London County Council, and continued by Dr. Frank Clowes, 40 Craven St., Westminster, S. W., Mr. Dibden's successor, it has been practically decided to change from chemical precipitation to septic tanks and contact beds. Mr. Maurice Fitzmaurice is chief engineer to the London County Council and Messrs. J. E. Worth and R. M: Gloyne, all of Spring Gardens, Westminster, S. W., are District Engineers in charge of the two great sewerage districts.

BIRMINGHAM, TAME AND REA DRAINAGE DISTRICT (792,603).—The first works built by the board for the treatment of sewage was a chemical precipitation plant. Later on, land treatment was added. The district now owns a valley some six miles long, including a total area of 2,830 acres.

Under the leadership of a new engineer, Mr. John D. Watson, Castle Bromwich, near Birmingham, the drainage board made a radical change in 1900. Chemical precipitation was abandoned and the operations of the farm were simplified.

Since 1900 the chemical precipitation tanks have been remodelled and new tanks built so all the sewage now has a brief period of sedimentation, followed by septic action in open tanks. Most of the septic effluent is applied direct to the farm, but some of it is treated on what Mr. Watson calls percolating filters. The filters in use at the time of my visit (March 31st) were all circular, of coarse material and the sewage was being applied by various types of revolving sprinklers. Other filters, rectangular in plan, and with fixed sprinklers were being built. These were for double filtration through coarse and fine material, respectively. There were also a number of Dortmund precipitation tanks under construction.

When the whole of the present scheme is carried out, the sewage will pass through the following stages: (1) rough or rapid settling; (2) septic tanks; (3) Dortmund tanks to remove the finely divided matter carried over by the septic tanks; (4) either single filtration through coarse circular filters with revolving strainers or double filtration through coarse and fine filters, provided with fixed sprinklers. The land not occupied by the various tanks and beds, which will be a large area, will be used (a) for treating storm water (b) for burying sludge from the settling tanks; (c) for treating the settled sewage pumped off before the sludge is removed from the settling tanks. The sludge, it may be added, is already pumped onto the sewage farm and buried in trenches, about 100 acres a year being required for that purpose.

GLASGOW (781,000).—In striking contrast to London, Birmingham and Manchester, Glasgow is steadily going forward with the construction of its second and preparing to build its third large chemical precipitation works. For the present, at least, no supplementary treatment will be attempted, and it is believed that none will be necessary for years to come. The sludge from the works now under construction will be shipped to sea. The precipitation tanks for the new works are 750 ft. long and 50 ft. wide, and the effluent from them will be discharged directly into the Clyde, which is only a few feet distant. Mr. A. B. McDonald is city engineer.

MANCHESTER (543,827).—The chemical precipitation works at Manchester are being closed down as rapidly as open septic tanks and single contact beds can be provided. The storm water flow is being treated in settling tanks and applied to single contact beds, also; but these beds receive some septic tank effluent when there is no storm flow, and are thus maintained in condition for immediate and efficient work. Land has been provided for second contact beds in case they should be necessary. Dr. Gilbert J. Fowler is chemist, and Mr. J. P. Wilkinson is engineer to the Manchester Rivers Department.

LEEDS (443,599).—Here is a veritable museum of experimental sewage works. Nearly everything of possible merit proposed in England of late years seems to have been given a trial or else is about to be put under trial. The city was defeated last year in an application to Parliament for authority to utilize some 2,000 acres for land treatment. The application may be renewed.

So far as the experiments are concerned they seem to point, I was told, towards continuous filtration, applying (1) either crude sewage and subjecting the effluent to sedimentation or (2) applying a good chemical precipitation effluent to the filter. For years the sewage has been treated by chemical precipitation. Mr. T. Hewson is city engineer of Leeds.

NOTTINGHAM (239,753).—I have been told by two men whom I consider good judges that Nottingham has one of the best managed sewage farms in England. The late Mr. James Avis assumed practical charge of laying out the farm in 1878, and he was farm manager until his death in 1897. He was then succeeded by his son, Mr. Arthur A. Avis, who had assisted his father for some ten years. The farm has been increased from 636 acres of leased land, to which sewage was first applied in 1880, to a present area of 1,950 acres, of which all but 173 is now owned by the city. The cost of the freehold land to the city averages about £110 per acre, making a total investment in land (and buildings) of about £1,000,000.

The city appears to have no idea of abandoning its sewage farm, and Mr. Avis sees little or no merit in any other method of treating sewage.

SALFORD (220,957).—Chemical precipitation here has been supplemented recently by continuous filtration through a single bed some nine acres in area, divided into sections or bays by supply and drain pipes. From the main supply pipes branch pipes with sprinkler nozzles deliver the treated sewage to the beds. The sludge from chemical precipitation tanks is shipped to sea. The tank effluent is passed through roughing filters of gravel before it is applied to the main filter. Mr. J. Corbett is borough surveyor of Salford.

LEICESTER (211,579).—This large sewage farm is unique in several respects: (1) The sewage of nearly the whole of Leicester is pumped 180 ft. to the farm, and the water supply of the borough is also pumped; (2) the land, save for a thin layer of top soil, is a very hard clay, which makes it necessary to rely largely on surface treatment of the sewage and to apply the first effluent from the surface, and most of the comparatively small amount from the under drains, to the land for a second time; (3) the sewage, after rough settling, is first applied to uncropped land, while the pick-up effluent is run on to pasture land (in other words, no crops are under sewage); (4) the main product of the farm is fattened bullocks. Owing to an insufficient area of land it is proposed to increase the tank capacity and to provide single contact beds for the preliminary treatment of the sewage before it is applied to the land. Mr. E. I. Mawbey is borough engineer and Mr. Willis Wigg is his first assistant.

OLDHAM (138,786).—Tanks have been provided here for the preliminary treatment of the sewage. Four of them receive the storm flow and seven the ordinary flow, all being operated for sedimentation only. The twelfth tank has been used for experimental purposes as a closed septic tank. The settled effluent is applied to single contact beds. The storm flow, up to about double the dry weather flow, also goes to the contact beds, but all above that amount has no treatment except the slight sedimentation afforded by the settling tanks. The sludge is pressed. Mr. A. H. Valentine is chemist in charge of the works.

BURNLEY (97,044).—There are two sets of six tanks here, all open except one. The first tank in each set is operated for sedimentation, only the effluent passing on to the other ten tanks. All these ten are septic and one of them is covered. The sludge from all twelve tanks is pressed. The tank effluent is applied to single contact beds. Mr. G. H. Pickles is borough engineer and Mr. Raymond Ross is borough analyst.

ROCHDALE (83,114).—Rough sedimentation is followed by chemical precipitation and the effluent from the latter is applied either to land or to double contact beds. In addition, one of the original chemical precipitation tanks has been used for some years as a septic tank and the effluent from it has been applied to small continuous filters, by means of revolving sprinklers. The effluent from these filters goes to small settling tanks. Mr. S. S. Platt is borough engineer of Rochdale.

YORK (77,914).—Although chemical precipitation works were installed only some eight years ago a change has been under consideration for a number of years. In fact, two of the six tanks are now used as septic tanks, and their effluent is applied to continuous filters, provided with revolving sprinklers. Further treatment is insisted on by the main authorities, but a final conclusion as to the method to be adopted has not been reached. Mr. Alfred Greer is city engineer of York and regards the septic tanks and continuous filters thus far in use as experimental.

READING (72,217).—The large sewage farm here was described in our issue of April 14, 1904, together with the Sandhurst and the Aldershot military sewage farms.

ACCRINGTON and CHURCH (49,585).—The original precipitation works were first changed to open septic tanks and contact beds, and later the contact beds gave way to continuous filters, with revolving sprinklers followed by sedimentation. Mr. W. T. Newton is engineer to these works and borough engineer of Accrington.

EXETER (47,180).—This installation includes detritus channels, closed septic tanks, double contact beds, and finally land treatment, with separate land treatment for a part of the storm water flow. Mr. Donald Cameron was until recently borough engineer of Exeter.

WATFORD (29,023).—The sewage is pumped to a farm; 130 out of 250 acres receiving the sewage. The land is underlaid with some 20 ft. of gravel. There are no underdrains, and it is said that there is no effluent. Mr. D. Waterhouse is engineer to the urban district council.

CHADDERTON (24,892).—Chemical precipitation works, followed by single contact filters, were built no longer ago than 1898. There is a small area of land, perhaps to treat the storm water flow.

SUTTON, SURREY (17,223).—The Dibden double contact beds, put down here in the old chemical precipitation tanks, are now receiving septic or partly septic sewage from open tanks. Supplementary works are also being built, and part of the new plant is in operation, combining septic action, a long and narrow settling channel, and triple contact beds. Mr. C. Chambers Smith is engineer to the urban district council.

SALISBURY (17,117).—We have here still another instance of chemical precipitation yielding place to plain sedimentation and open septic tanks, followed by further treatment. The filters are continuous, some with revolving sprinklers and some with fixed sprinklers. The effluent from these beds passes to some small shallow secondary beds designed to satisfy the demand of the local government board for further treatment. Mr. A. C. Bothams is city surveyor.

ALDERSHOT (about 17,000).—Notwithstanding the fact that the Aldershot Camp sewage farm has been such a success the combined chemical precipitation works and sewage farm owned by Aldershot town has been made over into works comprising a receiving and small detritus tanks, supplemented by (1) coarse contact and (2) fine intermittent filtration beds, the main part of the sewage farm being utilized for the treatment of storm water. Mr. Nelson F. Dennis is engineer to the town and Mr. Edwards is manager of the sewage works.

YEOVIL (11,000).—These works include detritus channels, closed septic tanks, double contact beds, with an isolating or aerating pool between the two sets of beds, and land treatment without underdrainage. Mr. A. Oddy is borough surveyor.

BARHEAD (10,000).—Detritus channels, closed septic tanks, an aerating trough and single contact beds are in use here.

GENERAL COMMENTS.

Up to some ten years ago the most common methods of sewage treatment in vogue in Great Britain were a combination of chemical precipitation and sewage farming, or sewage farming alone. To-day, many of the precipitation tanks, perhaps a majority of them, have been changed to either septic or plain sedimentation tanks, but a goodly number of chemical plants are still in operation and some new ones have been recently built or are now under construction, as witness Chadderton and Glasgow. It will be seen that while some of the sewage farms have been abandoned or virtually so, others are simply being relieved by works for the preliminary treatment of the sewage, and no inconsiderable proportion of the whole are being operated exactly as though the so-called bacterial methods had never been brought forward. This is particularly true at Watford, Reading, the Sandhurst and Aldershot military establishments and at Nottingham.

With the exception of some of the farms, none of the places relying on aerobic action for their final effluent try to get along without some previous treatment of the sewage, but that treatment may be plain sedimentation, chemical precipitation, or either open or closed septic tanks (generally open). The aerobic action is secured by a great variety and combination of methods; in fact, scarcely any two plants are alike in all their main features, while the details of the several plants are still more different.

The summary takes little account of methods of operation, in which there are also many variations; nor of the presence or absence of automatic dosing apparatus to charge the beds, which are absent in many cases and where present are quite varied in character.

Another marked diversity not taken account of in my summaries is underdrainage systems used for the filter beds, and still another is the lack of settled rules, or at least accepted rules, for (1) the proportion of the storm water treated and (2) the method of treatment. It may be added that the local government board has made a definite ruling on (1) and a fairly definite ruling on (2) but owing to the incompleteness of many of the works and various local conditions these rulings do not seem to be closely followed.

If one seeks for tendencies to uniformity the most that can be said is:

(1) The general order of the day is for change from chemical precipitation and broad irrigation to the newer and more rapid bacterial methods, which later frequently supplement the older methods named.

(2) Septic tanks, generally open, are common, but many plain sedimentation tanks have been noted.

(3) Contact beds and continuous filters are now rivals for favor, the latter being the newest, and, I should say, the more experimental.

(4) Where freedom from suspended matter is an object, the combination of septic tanks and rapid continuous filters is insufficient. It does not seem to be decided whether the added work for the removal of suspended matter should be done by sedimentation before or sedimentation after the continuous filtration, and it may be that secondary filtration will be better than either.

I trust no one will think that the foregoing comments are more than passing reflections, based on a review of actual works, and designed to indicate the great diversities and the main tendencies in practice at the works which I have visited. A mass of analytical results is being accumulated, based on both practical and experimental work. None of those results, and no figures of cost of construction or operation, have been taken into consideration in this letter, which is chiefly a bird's-eye view of some twenty-five actual works for the treatment of sewage.

Finally, I wish to call attention to the fact that local conditions, including existing works that of necessity had to be remodelled instead of abandoned, have had far more to do with the choice of the methods of treatment described than is generally taken into consideration, even here in England. American engineers and municipal authorities should beware of hasty conclusions based on what has been done or proposed at one or a few places in Great Britain.

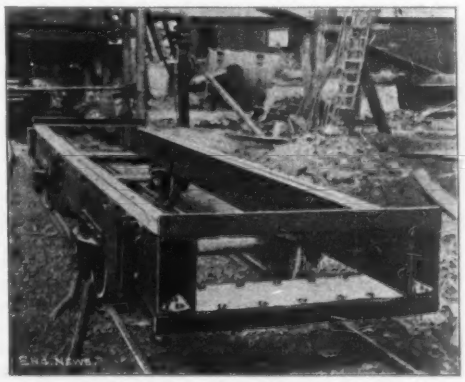
M. N. B.

Leicester, England, April 22, 1904.

A MOLD CAR FOR USE AT COPPER CONVERTERS.

The accompanying illustration shows a radical departure from the ordinary method of building mold cars for use under copper converters. The car as here designed allows the most commonly adopted width of frame, and at the same time maintains a 36-in. gage of track, which is the standard gage around all smelting works.

The frame is 16 ft. long over all and is made up of 10-in. channels with cast iron separators between. The bottom flanges of the channels are



Mold Car at Copper Smelting Works of Old Dominion Copper Co., Globe, Ariz.
Designed by Max J. Welch, M. E.

cut away at the wheels and angles are riveted to the opposite side. Short split-boxes are bolted directly underneath these angles, one box on each side of the wheel. In this way the axle is used as a tie for the frame, keeping the remainder of the space in the clear for dumping pigs of copper. The chief advantage in the arrangement is that the car wheels, bearings and rails are protected from copper dross while the converter is being poured.

The car is light in weight, has great strength and a neat appearance. It was designed by Mr. Max J. Welch, M. E., of Chicago, and has been installed at the new plant of the Old Dominion Copper Co. at Globe, Arizona.

THE LAKE CHEESMAN DAM.

The Lake Cheesman Dam is a masonry structure just being finished in the valley of the South Platte River to impound water for the supply of the city of Denver, Colorado. In a paper* read by Mr. Charles L. Harrison, M. Am. Soc. C. E., before the American Society of Civil Engineers, on May 4, 1904, the dam and the reservoir were described; and from that paper and the discussion that followed its reading, we have abstracted the salient features.

The plan of the dam is shown in Fig. 1, and its profile in Fig. 2. It will be seen that the dam is designed to resist thrust by virtue of its weight,

*The paper was printed in the "Proceedings" of the Society for March.

but that it is built in the form of an arch having a radius of 400 ft. on the intrados of the crest. This arch form was not given for the purpose of increasing the stability of the dam, but, as will be seen by studying the contours in Fig. 1, for the purpose of reducing the amount of masonry. No water flows over the crest, but a spillway 300 ft. long is provided on the left side of the valley; and the topography is such that even in flood time no back water will reach the down stream face of the dam proper.

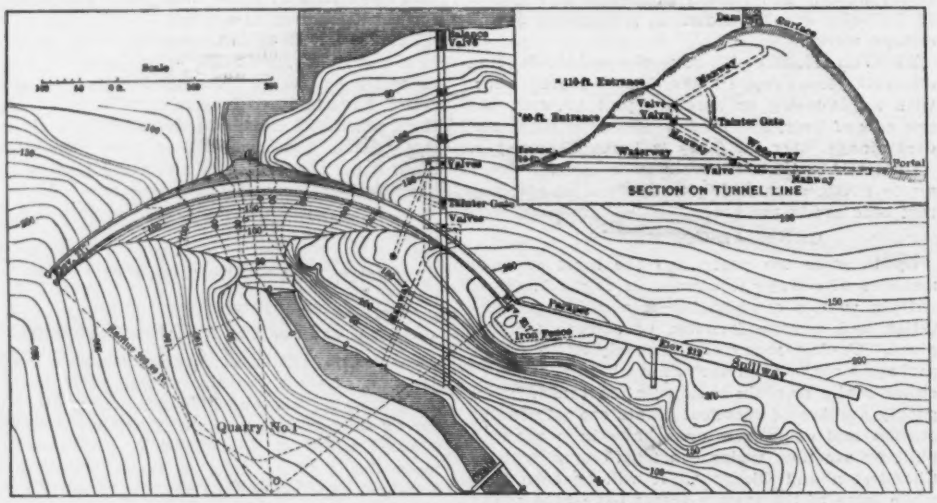


FIG. 1. PLAN OF THE LAKE CHEESMAN DAM.

The extreme height of the dam is 236 ft., and the extreme thickness is 176 ft. With water flowing 2 ft. deep over the spillway the pressure against the dam is that due to a head of 224 ft., which exceeds the depth of water against the face of any other dam yet built.

The dam will impound 3½ billion cubic feet of water from a water shed having an area of nearly 1,800 sq. miles; yet the maximum flood in June, 1900, was only 1,945 cu. ft. per sec. In the discussion, Mr. Kuichling questioned the accuracy of these figures, believing that a trifle more than 1 cu. ft. per sq. mile per sec. was not consistent with another statement made by the author to the effect that in April, 1900, the precipitation was 8.24 ins. To this, Mr. Harrison replied that the precipitation was practically all in the form of snow which in the eastern Rocky Mountains of Colorado melts off slowly, melting only in the day time.

The masonry is granite laid in Portland cement mortar; the weight of the masonry is 158 lbs. per cu. ft., 74% being granite and 26% mortar. The total amount of masonry is estimated at 103,000 cu. yds., requiring about 80,000 bbls. of cement, or about 0.78 bbl. per cu. yd. Mr. Davis, in the discussion, called attention to the fact that in the Boonton Dam, which was built of rubble concrete, the amount of cement was 0.68 bbl. per cu. yd. In the Cheesman Dam the mortar for the body of the dam is mixed in ratio of 1 to 2½, 95 lbs. of cement being taken as 1 cu. ft. The mortar for the face stone is 1 to 2. The sand contains 31% voids, and not more than 0.1% organic matter.

The granite was quarried in long blocks that were loosened with black powder, and then split up with plug and feathers. This gives stone comparatively uniform in size. The up-stream face stone were laid in 2-ft. courses, dressed to lay 1-in. joints. The down-stream face was laid in courses, but the stone was merely selected and not dressed. The backing was laid in soft mortar and well bonded. There has been no evidence of leaking or even sweating on the down-stream face under a head of 90 ft.

Tunnels and valves for controlling the outflow of water from the reservoir are illustrated and briefly described in the original paper.

The Cheesman dam is being built for The Denver Union Water Co. Mr. Charles L. Harrison, M. Am. Soc. C. E., was the designer and the Chief Engineer from June 1, 1900, to May 24, 1902; Mr. Alfred Noble, M. Am. Soc. C. E., and Mr. L. E. Cooley, M. Am. Soc. C. E., were consulting engineers. Mr. Alexander E. Kasti, M. Am. Soc. C. E., has been Chief Engineer since May 24, 1902. The Geddis and Seerie Stone Co. were the contractors for the excavation and masonry.

In the discussion that followed the presentation of the paper, Mr. Kuichling raised the question as to the allowance made for ice thrust. Mr. Harrison replied that ice can not form when the reservoir is full, and when it does form, the water will be so low that the effect of ice thrust need not be considered; moreover, the factor of safety would cover the effect of ice thrust even when the dam is full, to say nothing of the assistance derived from the arched form of the dam. Ice can not move in mass against the dam because a projecting hogback of rock lies parallel with the dam and only a few hundred feet above it.

Prof. Williams, of Cornell, was particularly interested in the mathematical discussion of the stresses in the dam, given by Mr. Silas H. Woodard, Assoc. M. Am. Soc. C. E., as a supplementary part of Mr. Harrison's paper. Prof. Williams believed, however, that an arch dam pure and simple might have been preferable to the gravity

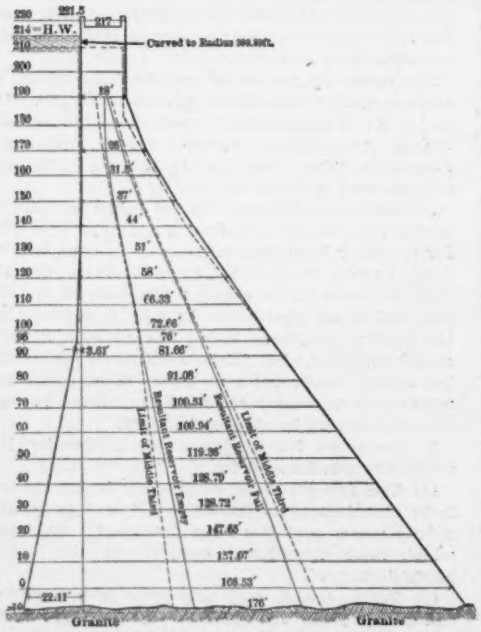


Fig. 2. Profile of the Lake Cheesman Dam.

form, and submitted a design of his own for comparison. His design was for an arch dam 90 ft. high to be built in a canyon near Ithaca, N. Y. It was to be only 8 ft. wide at the base. This dam was actually built to a height of 30 ft., when public opinion became so strong, on account of the fear of a failure of the dam, that work was discontinued.

Mr. E. Sherman Gould discussed at some length the subject of arch dams, stating that in his opinion the arch dam is destined to be the dam of the future wherever the span is moderate.

Mr. Smith, in speaking of temperature stresses, said that thermaphones had been embedded in the masonry of the Boonton Dam, and that records are being kept of the temperature curves. Two interesting facts had thus far been brought out, namely (1) that the temperature to which the masonry rises in the hardening is practically the same in cold weather as it is in warm weather; and (2) the temperature in the interior of the dam masonry has been steadily falling for more than a year. Moreover the temperature curve, even for the interior of the dam, shows a diurnal variation corresponding, although in a less degree, to the temperature curve in the open air. He wanted to know whether any cracks had developed in the Cheesman Dam. Mr. Harrison replied that at the end of the first severe winter no cracks had developed, but that he had heard that one vertical crack had developed near one end, on the down-stream face of the dam, although the crack was nowhere more than about 1-32-in. wide.

A COMBINED GRAVEL DIGGING AND SCREENING PLANT.

Gravel banks usually contain a mixture of pebbles and sand which should be separated into sizes whether the material is to be used for concrete, macadam or ballast. A compact plant especially designed for excavating and screening gravel is shown in Figs. 1 and 2.

A bucket elevator, suspended from a shaft, is fed forward into the gravel bank by cables, so that the cutting edge of the advancing buckets describes the arc of a circle, Fig. 2, ending at a point 20 ft. above the starting point. The struck capacity of each bucket is 0.7 cu. ft., and the speed of the buckets is about 100 ft. per min. When the machine is working against a 20-ft. face it excavates about 25 cu. yds. at each setting, cutting off a slice about 4 ft. thick. It takes ½ to 1 min. to shift the machine forward ready to take off another slice. The particular machine shown in Fig. 1 has a capacity of 30 to 40 cu. yds. per hour, the motive power being a 25-HP. engine and boiler, and the total weight of machinery and framework being 25 tons.

The gravel and sand are discharged from the elevator buckets onto a belt conveyor, which delivers to a rotary screen. The screen discharges into bins, from which the material is drawn off into gondola cars or wagons. The fine dirt, or dust, which it may be desirable to reject, is removed by a belt conveyor and deposited in a waste dump.

The mechanism of the plant is such that one man controls every motion. While the elevator is in operation the entire machine can propel itself backward or forward along the track. One other man, the fireman, completes the crew necessary to operate the machine; but, of course, additional men are needed to lay track, load the cars from the bins and attend to their removal.

The manufacturers, The C. O. Bartlett & Snow Co., of Cleveland, Ohio, state that they are prepared to make machines of this type of any size that may be desired; and, instead of a timber framework, a structural steel framework may be furnished.

SOME OBSERVATIONS ON STREET PAVEMENTS.*

By S. Whinery,† M. Am. Soc. C. E.

X.

Asphaltum for Pavements.

It may be safely assumed that the concensus of opinion in American cities gives sheet asphalt pavement the first place in point of merit, in so far, at least, as general utility and comfort in use are concerned. It is not, however, a perfect pavement. Its high first cost, and the difficulties and expense that have been encountered in keeping it in good repair, are undoubtedly the most serious objections against it.

To what extent and in what way can these objections be obviated, or, at least, lessened in force?

In regard to first cost, it may be confidently pre-

*Previous articles by Mr. Whinery in this series were published in Engineering News of Oct. 22 and 29 and Nov. 5, 1903.

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dicted that first class asphalt pavement cannot be hoped for at much, if any lower prices than those now prevailing. There are elements and conditions connected with its construction, even under the most favorable conceivable circumstances that add greatly to the first cost of the pavement and

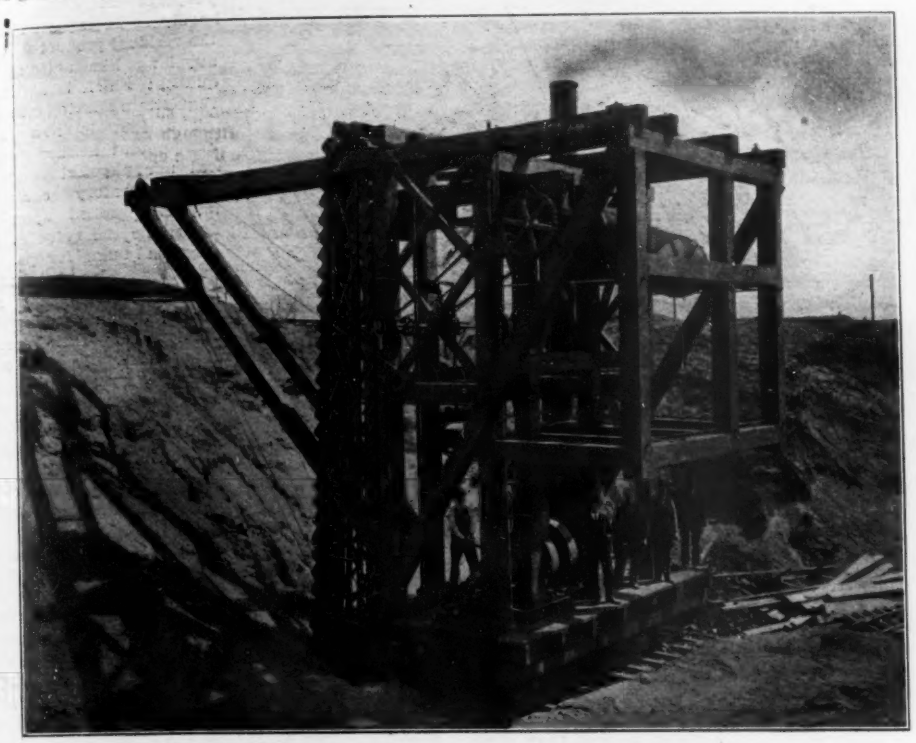


FIG. 1. A COMBINED GRAVEL DIGGING AND SCREENING PLANT.

that make any measure of that cost, based upon the cost of materials and labor only, incorrect and misleading. But it is now well understood that the first cost of any pavement is not a correct measure of its economy, this being determined by the quantity and quality of the service rendered per unit of investment. Relatively high first cost is not a valid objection against any pavement, if it be demonstrated that it yields more and better service per dollar invested than other pavements.

The cost of maintaining a pavement is an important element in making up the net balance of its efficiency and economy, and experience has shown that it is an element of considerable magnitude in the case of asphalt pavements. The question whether the cost of keeping asphalt pavements in repair can be materially reduced, is therefore one of great importance, and merits the most careful attention.

Other things being equal, the endurance of a pavement, and the cost of maintaining it, will bear a close ratio to the quantity of travel to which it is subjected. But this rule, as applied to any particular kind of pavement, is subject to modifications resulting from variation, not only in the quality of the materials used and the degree of fidelity and skill exercised in its construction, but also from the conditions of use to which the pavement is afterward subjected. In no other kind of pavement are these elements likely to vary so widely as in sheet asphalt pavement. This pavement, when skilfully constructed of the best materials, and subjected to use under conditions favorable to it, will endure an enormous quantity of travel with little care or expense for repairs. The fact that it does not always reach a high standard of efficiency is due to either improper construction or to unfavorable conditions of use.

It is not the intention in this article to go minutely into the subject of the proper quality of the materials used and the best ratio or method of compounding them—matters about some of which the best experts do not agree—but rather to call attention to some of the more important facts relating to the subject.

Broadly speaking, the composition which constitutes the wearing surface of a sheet asphalt pavement, is a concrete made up of inert mineral matter—sand and pulverized limestone—and the cementing element—asphaltum. Obviously the quality and utility of the compound will depend mainly upon the strength and the enduring quality of the cementing material.

Nearly all the earlier asphalt pavements and a great majority of the more recent ones, in American cities, have been constructed with asphaltic cement made with asphaltum from the great pitch lake on the island of Trinidad, it being, in the earlier history of the art, the only natural bitumen available for the purpose. It was quite early discovered that this asphalt, when exposed to water for a considerable period of time, undergoes certain physical or chemical changes that impair its cementitious value, but the importance of this defect was not at first fully appreciated. Even after other sources of asphaltum became available, the companies using the Trinidad product believed, for reasons that seemed at the time valid and sufficient—aside from the commercial interests involved—that upon the whole the Trinidad asphalt was the best material for pavements—as some of them do yet. But the more or less rapid disintegration of the pavement, where exposed to water or to excessive dampness, as, for instance, in the street gutters, and in pavements laid over water-bearing soil, or subjected to excessive flooding by sprinkling carts, has attracted more and more attention. The cost of repairs, under the usual guaranty conditions, has been burdensome upon the constructing companies, and has involved much trouble and expense to the municipalities after the guarantees have expired. Laboratory tests have shown that samples of the pavement immersed in water for any considerable period of time rapidly lose their cohesive strength and become practically worthless as paving material, the bitumen being apparently disintegrated and changed to an inert earthy appearing mass. Such a test is obviously severe, and perhaps unfair, since in actual use pavements are not submerged in water for considerable periods of time, but it demonstrates beyond question that the bitumen is subject to impairment by exposure to dampness or to water. The exact nature of the chemical or physical action of water upon this bitumen has not been determined, though much attention has been given to its investigation, and to the effort to discover a preventative or remedy. In the best recent practice an effort has been made to decrease the porosity of the pavement so as to exclude, as much as possible, the absorption of water into the interior of the pavement. Sands with a low percentage of voids have been selected, a larger ratio of pulverized limestone introduced, and the quantity of asphaltic cement increased, so as to approximately fill the remaining voids in the compressed mass. The results have been very encouraging, and these later pavements are undoubtedly much less affected by water than the earlier and more porous ones. An undesirable result of this practice, however, is that these richer and therefore softer and more plastic pavements yield more readily under the wheels of heavy vehicles increasing very materially their tractive resistance.

It is a curious fact that Trinidad asphalt placed in a comparatively weak solution of certain salts

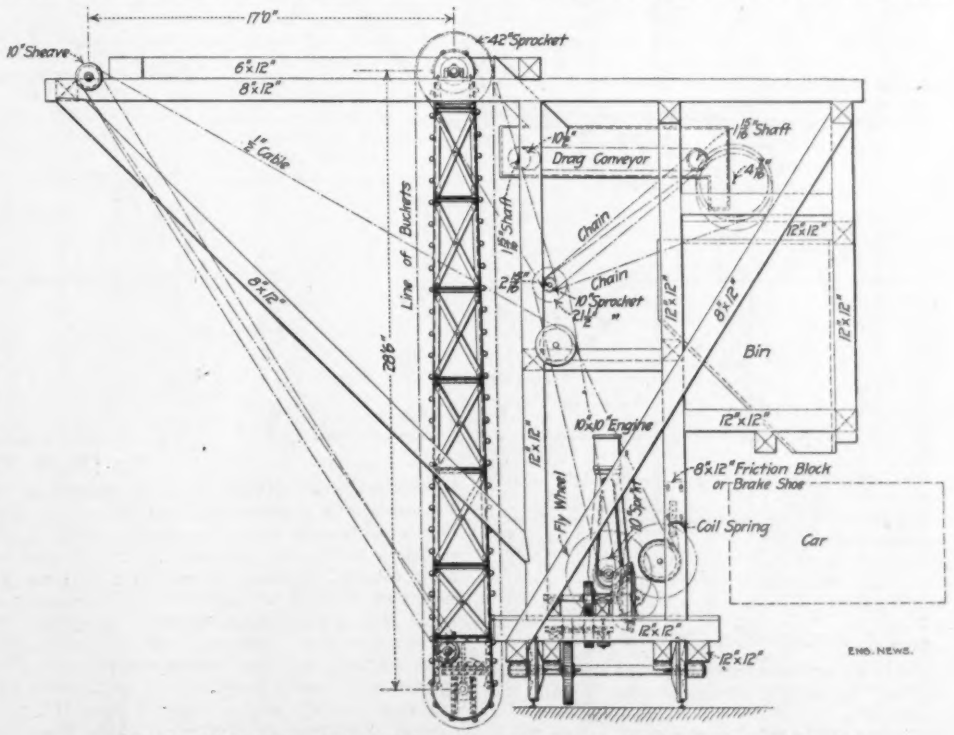


FIG. 2. SIDE ELEVATION OF GRAVEL DIGGING AND SCREENING MACHINE.

—common table salt being one of them—remains absolutely unaffected and unchanged for a very long period of time—certainly for several years. When this fact was discovered the experiment was tried of using a small quantity of common salt in the pavement mixture. Pavements laid with this

mixture were apparently unaffected by water, but they seemed to be inferior in some other respects and the experiments were abandoned.

Laboratory experiments have shown that all natural asphaltums are not subject to this disintegration in water in a like degree, and that some of them are apparently not affected at all, even when immersed in water for a long period of time. The question has naturally arisen whether those asphalts that are not affected by water, possess the other qualities requisite for a good asphaltic paving cement, and if so, whether it would not be wise to substitute them largely, if not exclusively, for the Trinidad asphalt now so largely used. In so far as laboratory tests may be depended upon, they seem to indicate that some of these asphalts from more recently discovered deposits possess all the necessary requisites for good paving cement, while immune from the deleterious action of water. If experience shall demonstrate them to be equal as a paving cement in other respects to the Trinidad product, pavements made with them should prove very materially more durable, and therefore more economical and satisfactory than those made from asphalts that are disintegrated by water. The purity of some of them is also largely in their favor from a commercial standpoint if no other. Refined Trinidad asphaltum contains only from 60% to 65% of bitumen, while some of these later discovered deposits yield a refined asphalt carrying over 95% of pure bitumen. In transportation this obviously means a saving of freight charges and cost of handling that is worth consideration.

It is appropriate that the city of Washington, where the American system of constructing asphalt pavements was first developed, and its merits demonstrated, should be the first to take practical cognizance of the desirability of finding an asphaltum, for use in pavements, that is not

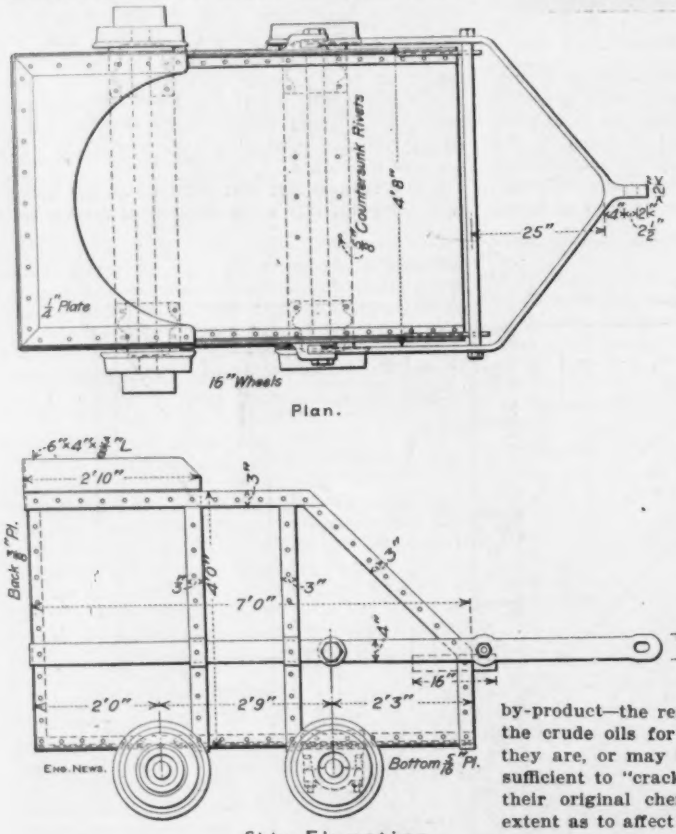


FIG. 2. SKIP FOR GRAVITY-INCLINE.

deleteriously affected by water. The specifications of that city for the season of 1903 contain this clause:

> Preference will be given to an asphaltic cement that is not readily affected by the action of water, provided it is satisfactory in other respects. If an asphaltic cement is accepted that is affected by water, some provision satisfactory to the Engineer Commissioner must be made to guard against the results of such action, and such work must be included in the price bid.

There can be no doubt that this is a conservative step in the right direction, and the results will be watched with great interest by the engineers of other cities. I believe it is safe to predict that before many years, asphalts, from whatever source they may come, that do not resist the deleterious action of water, will not be accepted for paving purposes, in our cities.

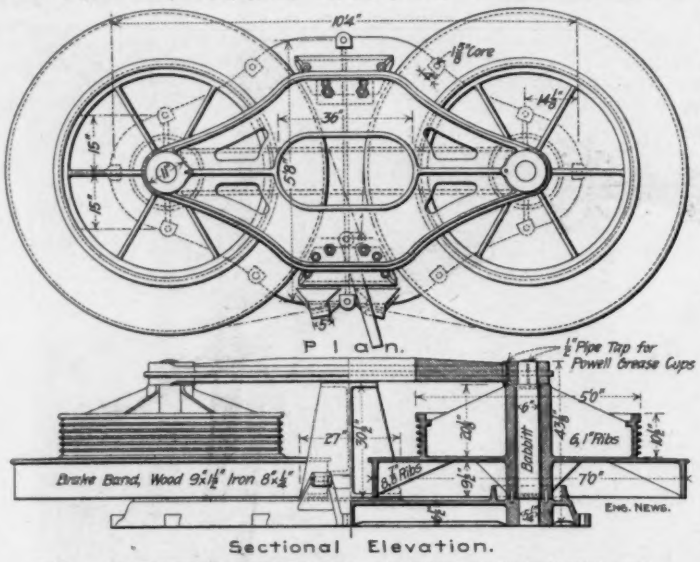


FIG. 1. LOWERING DRUMS FOR ANTONIO GRAVITY-INCLINE.

While upon the subject of asphalt for pavements, I wish to say a word of caution about the use of a class of bitumens that may be called "Artificial" to distinguish them from "Natural" bitumens; I refer to bitumens resulting from the destructive distillation of crude oils having an asphaltic base. I do not pretend to say that these bitumens, per se, may not be of excellent and even superior quality and entirely suitable for use in asphaltic paving cement. It must be remembered, however, that these bitumens, are in most cases a by-product—the residuum from the distillation of the crude oils for kerosene and other oils—that they are, or may be subjected to a temperature sufficient to "crack" and thus to alter or destroy their original chemical composition to such an extent as to affect unfavorably their cementitious value, and to make them, therefore, unsuitable for use in pavements. Granting that all natural bitumens probably had their origin in natural deposits of petroleum, which have become oxidized by exposure to the air during geologic ages, the process of their production is so different from the quick distillation at high temperatures of these so-called "Artificial" bitumens as to warrant a doubt of the practical sameness and value of the two products. It may readily be conceded that where the distillation is conducted with great care, with the primary object of producing a superior article of bitumen, the product may be of satisfactory and uniform quality; but that is not usually the case, and when it is remembered that these bitumens are distilled at different works, from different crude oils, by different men or companies, by different methods and with different purposes in view, it is hardly to be expected that the residual product will be anything like uniform in quality; which is a prime requisite in a paving cement.

The fact is now well known that neither chemical nor physical tests in the laboratory can be implicitly relied upon to determine the value of an asphaltum for paving purposes, though such laboratory tests may aid materially in forming an opinion of their probable value. In the end, actual experience on heavy traveled streets, under the various conditions of use, must be depended upon to determine the value of each variety of asphalt, and even here hasty judgment must be guarded against. Each new asphaltum is likely to require somewhat different treatment in the details of its handling and the composition of the mixtures made with it, from others, and some little time may be required to develop its actual value. When Bermudez asphalt, now recognized as a standard material, was first introduced, laboratory tests seemed to indicate that (judged by standards then accepted) it was decidedly inferior to Trinidad asphalt, and the earliest trials of it in pavement seemed to confirm that opinion, but more skillful construction of the pavement soon demonstrated its good qualities.

The discovery of new deposits of asphalt and the development of others previously known to exist, have brought a practically unlimited supply into the market, and our cities may now choose from among them that kind which, all things considered, shall be demonstrated to produce the most satisfactory, and truly economical pavement.

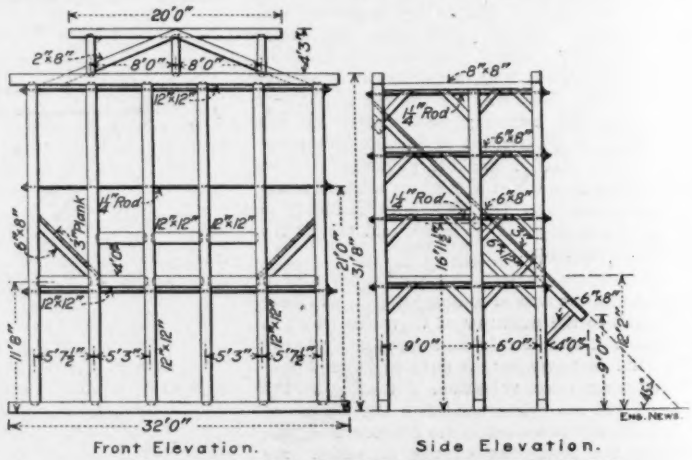


FIG. 4. BOTTOM POCKET OF GRAVITY-INCLINE.

A GRAVITY INCLINE AT THE ANTONIO MINE IN CUBA.

By E. M. Holmes.*

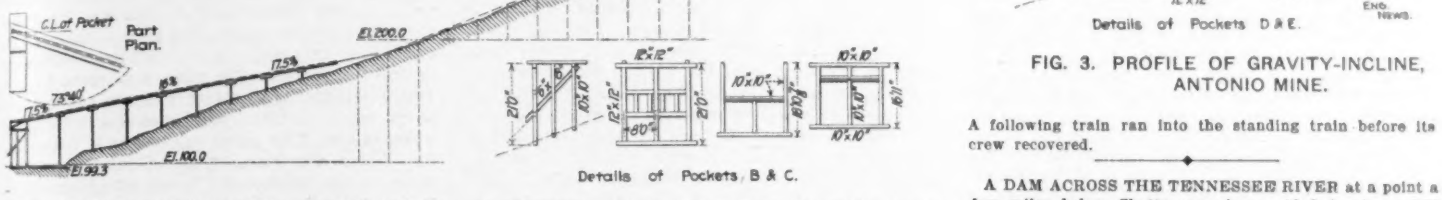
The iron mines of the Spanish-American Iron Co. are located at Daiquiri, 16 miles east of Santiago, Cuba. The officers are: Mr. Chas. F. Rand, President, 71 Broadway, N. Y.; Mr. Jennings S. Cox, Jr., General Manager, Santiago; and Mr. G. W. Pfeiffer, Superintendent, Daiquiri.

Six months ago these mines passed their two million ton mark. At Daiquiri, their shipping point, they have a steel ore dock, of the same

*Engineer Spanish-American Iron Co., Daiquiri, Santiago de Cuba.

construction as the ore docks of the Great Lakes, from which a standard gage railroad, of 2% maximum grade, runs to the foot of the hills on which are located the mines, 4½ miles inland. From the mines to the tracks the ore is lowered by gravity, and the company now operates ten gravity inclines.

The first of the year it was decided to install a new incline at the Antonio Mine to increase the output of a body of ore below the top of the present inclines. As the mines are worked in levels 40 ft. apart, vertically, it was decided to put an intermediate pocket of 60-ton capacity at each level to receive its corresonding ore, which is trammed from the cut to the incline. However, the top level contained much less ore than the others, and would be exhausted first if equal quantities were removed from each level, consequently it was decided that one car should act at times as a counterweight by carrying a small quantity of ore, and only loading the other at the desired pocket. By alternating, both sides of



the intermediate pockets could be emptied and the bottom pocket be filled uniformly.

On our former inclines the car lowers three tons, and from loss of time, in running one car as counterweight, this size would be inadequate to lower the required quantity per day; to offset this, it was decided to double the capacity of the car, or lower six tons. Special machinery had to be cast and new cars made.

The construction work was started in March, 1903, and finished in October. The total cost of the incline, including extra parts for the machinery, was $17,830.64; and while it has never been tested to its full capacity, it has lowered 1,400 tons in a day, and on a 1,300-ft. incline, with no intermediate pockets; where both cars run full, it will easily lower 2,600 tons per day of ten hours, requiring but two men to operate it.

The machine and cars are shown in Figs. 1 and 2. The hoisting rope is 1½-in. steel cable; all the machinery was furnished by Earle C. Bacon, 26 Cortlandt St., N. Y., and he has also furnished the equipment for ten gravity and three hoisting inclines now in use.

The pockets are sided and floored with 3-in. yellow pine and lined with ¼-in. steel plates secured by countersunk bolts.

The trestle bents are 8 × 8 ins., supporting six 8 × 16-in. stringers on a 30-ft. span; 60-lb. rails are laid on native hardwood ties to a 5-ft. gage.

The grades are shown in Fig. 3; and the bottom pocket, of 175-ton capacity, in Fig. 4. The ore is deposited in this pocket by the skip, which is self-dumping, and lowered by a hand operated gate into 25-ton hopper bottom cars and hauled to the dock.

On account of waste banks, and an incline from the Lola mine, the location is on the opposite side of the Lola incline and trestles from each cut, to its corresponding pocket, pass overhead.

No difficulties were encountered in the execution of the work, and this incline, while a new departure, has demonstrated that an incline with large cars is far superior to the small ones, both in capacity and in economy in building, operating and maintaining.

STEAM TURBINES IN NAVAL SERVICE are to be tried by the Navy Department on two of the new scout vessels for which Congress made appropriation. One vessel will be equipped with Parsons turbines, one with Curtis turbines, and a third will have reciprocating engines in order that a comparison of the three under similar conditions may be made.

ANOTHER LONG ALPINE TUNNEL is approaching completion. This is the Bosruck tunnel, 4,700 meters in length, which is being driven through a mountain range to give a new railway connection from Bohemia to the Adriatic. Work on the tunnel was begun in 1902 and it is expected to have it completed and the line ready for traffic in October, 1905. An account of the work in "The Engineer" of April 22 states that as there is no good sand in the vicinity of the work, crushed stone has been used instead in mixing mortar and concrete.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a derailment on the New York, New Haven & Hartford Ry. main line at the Byram River, near the state boundary between New York and Connecticut, at 1.30 a. m. on May 10. The train was made up of six Adams Express cars, run on a fast schedule and carried no passengers. At the Byram River the switch was set to turn it from the express track to the outside or local track and the signal was set at the preceding block station to notify the engineer of the changed switch so that he might slow up before passing over it. He failed to do this, however, and ran over the switch at a speed estimated at 60 miles an hour. The locomotive, tender and first two cars left the track and went down a high embankment. The engineer and fireman were killed.

A REAR COLLISION on the Manhattan Elevated on May 9 instantly killed the motorman of the colliding train and telescoped one car. A train was stopped by a track repair gang and the train following ran into its rear; the most probable explanation of the accident is that the motorman of the rear train did not realize how near he was approaching the standing train until he was too close to stop before striking it.

A RECORD OF LARGE FIRES that have occurred in the United States and Canada has been published by the National Board of Fire Underwriters. This record is not presented as including all fires in which the property loss ran into large figures, but it does include practically all the fires that have proved calamitous either because of the direct money loss or because of the destitution wrought on the community. The list is given in the table below:

Date.	Place.	Property destroyed.		Loss.
1820.	Savannah, Ga.	463	Buildings	$4,000,000
1835.	New York, N. Y.	530	"	15,000,000
1838.	Charleston, S. C.	1,158	"	3,000,000
1845.	New York, N. Y.	300	"	7,500,000
1845.	Pittsburg, Pa.	1,100	"	10,000,000
1848.	Albany, N. Y.	600	"	3,000,000
1849.	St. Louis, Mo.	15	Blocks	3,000,000
1850.	Philadelphia, Pa.	400	Buildings	5,000,000
1851.	San Francisco, Cal. (May)	1,000	"	10,000,000
1851.	San Francisco, Cal. (June)	500	"	3,000,000
1866.	Portland, Me.	1,743	"	10,000,000
1871.	Chicago, Ill.	17,430	"	168,000,000
1872.	Boston, Mass.	776	"	75,000,000
1879.	New York, N. Y.		Dry goods buildings	3,500,000
1881.	Quebec, Que.		One-fifth of city	2,000,000
1889.	New York, N. Y.		Elevators and wharves	3,000,000
1889.	Seattle, Wash.		Business section	5,000,000
1889.	Spokane, Wash.		Large part of city	6,000,000
1889.	Boston, Mass.		Bedford Street buildings	6,000,000
1889.	Lynn, Mass.	300	Buildings	5,000,000
1892.	New Orleans, La.		Dry goods district	3,000,000
1892.	New Orleans, La.		Business district	3,000,000
1892.	St. John, N. F.	600	Buildings	25,000,000
1892.	Milwaukee, Wis.		Business buildings	6,000,000
1893.	Boston, Mass.		Business buildings	4,500,000
1895.	San Francisco, Cal.		Factory and buildings	2,000,000
1897.	Newport News, Va.		Buildings and ships	2,000,000
1897.	Pittsburg, Pa.		Business buildings	2,000,000
1897.	Windsor, N. S.		Entire Town	2,500,000
1898.	Pittsburg, Pa.		Chautauqua building	2,000,000
1898.	San Francisco, Cal.		Baldwin's Theatre, etc.	2,000,000
1898.	Terre Haute, Ind.		Business section	1,850,000
1899.	Dawson City, B. C.	111	Buildings	3,000,000
1899.	Victor, Colo.	800	Buildings	2,000,000
1899.	Philadelphia, Pa.		Business block	3,000,000
1899.	Ottawa and Hull, Canada		Large section	15,000,000
1900.	Hoboken, N. J.		Piers and vessels	5,500,000
1900.	Bayonne, N. J.		Oil works	4,500,000
1901.	Montreal, Que.		Business buildings	3,000,000
1901.	Jacksonville, Fla.	148	Blocks	11,000,000
1902.	Waterbury, Conn.		Business blocks	3,000,000
1902.	Paterson, N. J.	26	Business blocks	7,000,000
1903.	Cincinnati, O.		Opera house and buildings	2,000,000
1904.	Baltimore, Md.		General conflagration	75,000,000
1904.	Rochester, N. Y.		Business blocks	3,000,000
	Total			$539,850,000

A FREIGHT TRAIN CREW overcome by gas caused a rear collision on the Delaware & Hudson R. R. at the tunnel 12 miles east of Binghamton, N. Y., on April 22. The whole crew of an east-bound train were stupefied by gas in passing through the tunnel and the engineer was only conscious enough to stop his train after passing through.

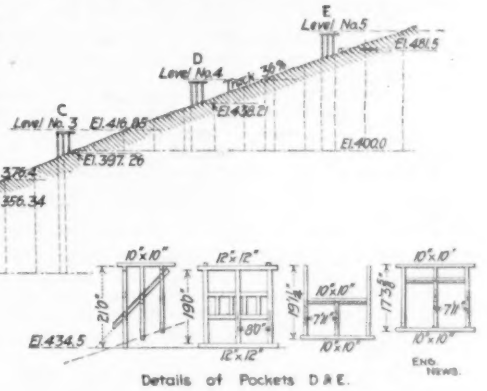


FIG. 3. PROFILE OF GRAVITY-INCLINE, ANTONIO MINE.

A following train ran into the standing train before its crew recovered.

A DAM ACROSS THE TENNESSEE RIVER at a point a few miles below Chattanooga is provided for by a bill which passed the last Congress. There is an available fall of water of about 25 ft., and the low water discharge of the river is about 8,000 cu. ft. per second. The bill permits the City of Chattanooga to build the dam if it exercises the option within four months, otherwise the right reverts to a syndicate of local capitalists. The dam and steamboat lock adjoining must be constructed under government direction and opened for free navigation, but the builders have the right to use the overflow water for power purposes.

A TIE AND TIMBER DEPARTMENT has been established by the Atchison, Topeka & Santa Fe Ry. The head of the department will have charge of all tie and timber preserving plants, and the managers of these plants will report to him. All officers in charge of maintenance of track, bridges and buildings will report to him concerning matters connected with the greater durability on extension of service of ties and timber. The department will maintain a record, showing the location of all treated and untreated ties placed in the track, and all timbers used in bridge structures each year, together with the dates of removal of ties and timbers, and the reason for such removal. Mr. E. O. Faulkner has been appointed Manager of this department, with headquarters at Topeka, Kan., and he will report to Mr. J. W. Kendrick, Third Vice-President.

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We give large space in this issue to a valuable paper by a railway engineer in Australia upon the application of the principles of economic railway location, as developed by the late A. M. Wellington, to the conditions existing on the Australian continent.

Professional literature on railway location has become quite voluminous, but nearly the whole of it relates to the location of railways which are expected sooner or later to carry a heavy traffic. There is very little to be found anywhere to guide the engineer in the task of building a branch line railway whose traffic is, and in all probability always will be, very small in amount. Yet the mileage of railways of this class is far greater than the mileage of the trunk line railways.

The paper by Mr. Fraser above referred to relates largely to the location of light traffic railways, and it is partially for that reason that we have felt justified in giving it an amount of space which we seldom devote to any single contribution.

There is one important feature in which the location and construction of a light traffic railway line differs radically from that of a line for heavy traffic which we do not remember to have seen anywhere definitely stated, and we therefore propound it here as follows:

A heavy traffic railway should be located and built to save expenditure in the movement of trains. A light traffic railway should be located and built to save expenditure in maintenance of way.

Assuming at the outset that a railway is built to earn profits and that the best railway location, as Mr. E. H. McHenry has well expressed it, is that which makes a dollar earn the most interest, the best railway line for light traffic is the one for which the interest charges on first cost plus the cost of maintenance of track and structures will be the least in amount. Of course a line must have such grades and curves that it can be operated with safety, but speaking broadly it will seldom be found on lines of very light traffic that an increased expenditure in construction will save anything of any amount in the cost of train movement. Trains enough for public accommodation must be run anyway, and these trains will usually take all the traffic there is to be carried. The trifling amount of coal saved by the use of smaller locomotives on a line of easier grades will usually be a mere trifle compared with the interest on the cost of obtaining such grades.

In the maintenance of way department, however, the situation is reversed. Unless the money which can be obtained for construction is closely limited, it will pay to spend a good deal on the construction of a light traffic line to save annual expenditures in maintenance. For example, drainage ditches and culverts may be built in the cheapest way possible with the result that in two or three years a heavy rain storm occurs and a large bill of expense must be incurred for repairing washouts. Steep slopes on cuttings reduce the cost of construction, but result in a long period of trouble afterward with earth slides and choked ditched.

When Wellington wrote his treatise on economic railway location he advised the liberal use of temporary wooden structures in order to save in first cost in building light traffic lines. Conditions since then have changed so greatly that, save for a few sections of the United States, the use of timber structures in railway construction is, as a rule, a wasteful and unwise practice. Timber is so expensive that instead of using it for temporary structures, it is better, even on roads where economy in first cost is of the highest importance, to build permanent structures at once. Culverts and short bridge spans of concrete or reinforced concrete are cheaper by far than either wooden or steel structures. Station platforms of wood are an expensive luxury on even the cheapest roads. If concrete cannot be afforded, then broken stone or gravel or even engine cinders may be used. In short, for the most economical construction of a railway for light traffic we must make use of materials which will neither rot out nor rust out. It is better by far to spend money here than in making deep cuts, high fills and easy curves beyond what are necessary to make a roadbed over which trains can be moved and which will be fairly secure against storms and floods.

One of the most difficult legal questions raised by the progress made in the utilization of water for irrigation and municipal supply, is the adjustment of the relative rights of different states. Where a river crosses a boundary line, it frequently happens that the users of water on the upper courses will drain the stream dry, and those who have built irrigating ditches in another state farther down the stream, find their works useless and their crops a failure in consequence. A similar question now arises with respect to the Rio Grande and Colorado Rivers, which rise in the United States but flow into Mexico. In the case of the latter stream the Mexican Ambassador has just filed with the State Department a protest against the proposition to divert the waters for irrigating desert lands along its course in Arizona.

It is a pretty well settled principle that the riparian owner of land on the lower courses of a stream has rights which the riparian owners above are bound to respect. In England, where a city appropriates streams for a water supply, it is not permitted to take the entire flow of the stream, but has to furnish "compensation water" to offset the amount which it takes. Of course, by building reservoirs in a drainage area the flood flow is stored so that a city can use a large percentage of the run-off and still permit water enough to pass down the natural channel to serve the needs of the riparian dwellers and users of water power below.

The same principle ought to prove a solution to the international question concerning the waters of the Rio Grande and the Colorado. If the United States, by building storage reservoirs on these streams, can store the flood waters, it can maintain the low water flow unimpaired and Mexico will have as much water in the channel at low water stages as before. The stored flood waters can then be utilized in the United States for irrigation.

Many of our readers will recall the agitation which was carried on for many years to obtain for the steam engineering staff in the Navy the recognition and standing to which it was believed to be fairly entitled. The final outcome, five years ago, was the transfer of all engineer officers to the line and the issuance of an order that line officers should discharge the duties formerly assigned to the steam engineers. In defence of this plan it was said that all naval officers nowadays ought to be competent engineers and able to perform the duties of either the engine room or the quarter deck.

While this plan gave the engineer officers that for which they had long been contending, in its practical working the tendency has been for the officers to transfer the actual responsibilities in the engine room to the enlisted force of machinists, and the fear has been expressed that the Navy would be found lacking in experts practically familiar with the details of steam engineering work. To meet this situation, Secretary Moody has just put in force a new plan which aims at the creation of a body of line officers who shall be specialists in steam engineering and another body who shall be specialists in ordnance. At the present time two Junior Lieutenants, four Ensigns and four Midshipmen are to be assigned exclusively to steam engineering work, and the same number are to be assigned to ordnance work, such as inspection at the gun factories, etc. Four midshipmen are to be added each year to the ordnance corps thus created, and four others to the steam engineering corps. The officers assigned to these duties remain line officers and the ordnance officers are to perform line duties like other officers when at sea. The steam engineers are not to have line duties when at sea, or, in other words, will not have the opportunity to command vessels; but in compensation for this they are to have shore duty exclusively after attaining the rank of Commander.

It will be apparent from the very small size of the corps thus created, that it will be a small factor in the actual care of the engines of vessels in commission. Both these men and those assigned to ordnance work are apparently intended to constitute a body of special experts, competent to guide the Government wisely in the solution of difficult problems in each of these important fields.

In discussing the question of the protection of water supplies in our issue of April 28 we urged that more attention should be paid to the development of sources of underground water supply for places of moderate size, particularly those located in districts of the West and South, where an unpolluted supply from surface streams is also impossible to secure.

At Waterloo, Iowa, the matter of a pure water supply has recently received great attention by reason of the typhoid epidemic during the first three months of the year involving some 300 cases of the disease and 30 deaths. Water is taken from the Cedar River, the intake being located in the heart of the city, and is filtered in gravity mechanical filters, which, however, as shown in the report published in our issue of March 31, failed to remove the typhoid germs. An investigation of the water supply has now been made by Prof. A. Marston of the Iowa State College on behalf of the city, and Mr. Geo. A. Johnson of New York for the water company, and they have advised changes in the filter plant which are now being made. In addition Prof. Marston has recommended that three artesian wells be bored to determine whether a sufficient underground supply can be developed for the city's needs. In case this cannot be done he advises the installation of slow sand filters with a sedimentation basin of 24 hours capacity arranged so that coagulant can be applied when found necessary at the time of freshets and in the spring when the water is discolored from decaying vegetation. Professor Marston strongly advised that in connection with any filtration plant expert supervision and daily bacterial tests should be provided for, although the plant would be a comparatively small one.

This report is of particular interest because the situation at Waterloo is typical of that of hundreds of towns and cities in the Mississippi valley. Water is being taken almost invariably from surface streams, which answered well enough when the country was new and thinly settled and when the dangers of impure water were unknown. But the condition of these streams grows worse every year and the only attempts at purification

have been mechanical filters, which were often installed with no idea of doing more than remove the mud held in suspension. There are no slow sand filters in all that region and the recommendation by an engineer that either an underground supply or purification by such filters is essential to a safe water supply is a fact worth particular note.

The leading fire insurance companies of the United States have undertaken, through a committee of the National Board of Fire Underwriters, the very important task of investigating the fire risk and means for fire protection of American cities. This undertaking has been in mind for some time, but the work of carrying it out has been hastened by the Baltimore conflagration, and the large fires at Rochester, N. Y., and Toronto, Canada. As we understand the plans, it is proposed to employ a body of trained engineers to investigate fire risks and report upon them, with suggestions for improvements in the nature both of fire resisting construction and of organization and equipment for fighting fire. Incidentally, the knowledge thus gained will be used as a basis for urging legislation which will bring about better conditions in respect to the fire risks of our large cities. There can be no question about the necessity of the work outlined; the Baltimore fire proved this, and the proof was clinched by the fires at Rochester and Toronto. Recently, moreover, evidence has been furnished by the investigations of the National Board of Fire Underwriters at Chicago that the conditions found at Baltimore are common to many if not all American cities. Summarized briefly the report shows that there are large areas of Chicago, including the mercantile center, that offer no better surety against conflagration than did the burned district of Baltimore; that the water supply is inefficient, and that the fire department is inadequate, both in men and apparatus, to deal with a fire of large proportions. To quote briefly:

> Disastrous fires are liable to occur within the congested mercantile and manufacturing section, extending north to Erie St., south to Harrison St., east to Lake Michigan, and west to Halsted St. In this district there are many old and poorly constructed buildings, with multiple occupancy and filled with highly combustible material, a menace in case of fire to surrounding property. Throughout the business section, where vast values are concentrated, there are numerous paved and unpaved narrow alleyways, in width from 8 ft. to 15 ft., with rear and side facing walls of tall buildings, a serious hindrance to successful fire fighting. In many instances protective shutters were found open on nearly all buildings during the night-time, and there are numerous exposed buildings with unprotected external openings and inflammable window frames, which would naturally aid the extension of fire to other buildings across these narrow thoroughfares and beyond the reach of the present deficient fire-fighting facilities.

These are exactly the conditions that prevailed at Baltimore, and who can doubt that similar conditions exist in at least large parts of every other American city of the first class. To indicate that this is not an abnormal conclusion we quote the following extract from a report on the Baltimore fire, made by Mr. F. M. Griswold, General Inspector of the Home Insurance Co.:

> In relation to the rapid spreading and almost uncontrollable fury of the conflagration in this city, it may be truly said that it was not due to any special condition which might be applied to this city alone, but is such as we find existent in many of our older cities, where, as here, narrow streets, light and readily inflammable structures, filled with more readily combustible materials, and, above all the almost absolute lack of proper protection against mutually exposing wall and roof openings, and wooden cornice exposures, present as a single risk open to burning not only a city block, but equally groups of such when contiguous and subjected to the untoward condition of the elements and the usual demoralization consequent upon such events as have accentuated the incipiency of the conflagration in this unfortunate city.

These thoughts are not presented here because they are new, but so that their truth may be impressed by repetition on the public mind. There is a fertile field in every American city for the work that has been undertaken by the National Board of Fire Underwriters and we trust that they will not hold their hands until all the good that is to be had has been gotten from it.

IMPROVEMENTS IN THE DESIGN OF MACHINE TOOLS.

One of the important matters now receiving the consideration of managers of machine shops is that of increasing the economy of work done on machine tools. Practice in machine tool work has been literally revolutionized during the past half dozen years, first, by the introduction of high-speed steels which permit the cutting of metal at rates which were wholly undreamed of a short time ago, and, second, by the application of electric motor driving to machine tools, which has in many instances greatly increased the facility of handling the machine, and thereby increased its possible rate of output. In addition there has been rapid progress in the specialization of machine tools. Machines produced in quantity can no longer be made on the ordinary lathes and planers which were the standard and about the sole power tools in the old-time machine shops. In the days when single tools were built to order such methods sufficed; but a great proportion of the output of modern machine shops is manufactured and not built, and rapidity of production is the essential element which the shop manager must attain if profits are to be earned.

In order to take advantage of the capabilities of modern machine tools, however, systematic records of the work of men and machines are found to be of great advantage. In the old-time machine shop the foreman had a fairly clear idea (obtained from long experience) as to how much a lathe hand or planer hand ought to accomplish; but changes have come so fast that the present day foreman does not know and cannot be expected to accurately know how much work an expert operator can produce from each special tool. Hence arises the necessity, in fairness to the workmen as well as to the employer, of some system of rating machine tools, and we may add of some system of compensating labor that will induce the workmen to develop the full capacity of the tools.

In our issue of Dec. 31, 1903, we gave an abstract of a paper dealing with this part of the subject by Mr. De Voy, of the Chicago, Milwaukee & St. Paul Ry., in which was shown the desirability of ascertaining the practicable minimum of time to be allowed for the several processes involved in such work as turning tires, planing and slotting boxes, etc., and a form of card index was suggested for these various ratings.

In the same issue we also printed another paper* bearing on the important question of the design of tools to stand the strain of high-speed steel cutting tools and electric motor driving, a question to which both makers and users of machine tools are giving serious attention. There may be tools so substantially built that they need no alterations in general design when they are speeded up to double or treble their former rate of work, but they are probably the exception and not the rule. Particularly is this true of the framework of the machines. It will be remembered of course that conditions in machine tool design are radically different from those in a bridge or a hoisting machine. The machine tool must not merely have its parts proportioned to the stresses they are to bear, but it must be designed throughout with a view to minimum deflection of its parts, where such deflection means inaccuracy in the work produced.

It is quite true that the makers of machine tools are continually introducing improvements in their machines, but as high-speed steel cutting tools are not likely to be generally adopted for ordinary work, at least for some time to come, the manufacturer naturally desires to build and sell his regular lines of machines. The purchaser, on the other hand, desires to get the best work out of the machine, and if he cannot find a machine in the market to meet his particular needs, he may devise one for his purpose. Within the past few years great numbers of special machine tools have been built. Some of them are the results of manufacturers' attempts to improve over their competitors, but very many of them represent the designs or requirements of purchasers who wanted results not attainable by the regular styles of machines.

An interesting comparison of the opposite views of the makers and users of machine tools is afforded by the following quotations from two papers recently read before the Western Railway Club:

(1) The range of feeds and speeds has been enlarged until, with the additional power supplied, the only limit is the durability and strength of the cutter. . . . One difficulty has been to get the purchaser to specify exactly what he wants in feeds and speeds. I am sure if he would make definite statements on these points and then leave the production of the machine to accomplish these results to the designer and manufacturer, all would be better satisfied.—Mr. James K. Cullen, President of the Niles Tool Works (Eng. News, Dec. 4, 1902).

(2) It is a fact that no machine shop is to-day fully equipped with machine tools which can use high-speed tool to the limit of its endurance; nor are machine-tool makers prepared to-day to furnish all classes of tools capable of obtaining maximum service from high-speed steel. It is not claimed that there are no machine tools which will do this, but they are a small minority. . . . The makers of machine tools have had to wake up to the fact that heavier and more powerful machines must be made to keep up with the working capacity of high-speed steel, and I venture to prophesy that heavy machinery is as yet in its infancy.—Mr. J. A. Carney, Master Mechanic of the Chicago, Burlington & Quincy Ry. (Eng. News, Dec. 31, 1903).

In the discussion of Mr. Cullen's paper (above quoted), his statement that the limit of the machines was the durability and strength of the cutting tool, was at once combated. It was shown that in many cases, even with modern machines, it is the machine and not the cutting tool which sets the limit. To this Mr. Cullen replied that the development of high-speed steel has been so rapid that machine manufacturers had found it impossible to meet all conditions, but that they were then prepared to meet the most exacting demands. A year later, however, Mr. Carney repeated the claim that the machine tools are not built to the capacity of the tool steel.

In this connection we may refer briefly to the question of purchasing machine tools on specifications, which is discussed in another column of this issue. This practice as yet prevails to a very limited extent, and is mainly confined to large and important tools. In view of the general tendency to extend the use of standard or uniform specifications in various lines of engineering it seems quite likely that this practice will grow.

In conclusion we may quote as one of the best summaries of needed development in machine tool design, the following extract from a paper by Mr. Dodge, presented before the New York Railroad Club a year ago:

> It is to be expected that the modification in design of machine tools of all classes, to make them the superior of the tool steel, should take time far in excess of the almost meteoric improvement in the cutting tools. It is gratifying to note, however, that machine tool builders are keenly alive to the necessities of the case, and to note with what signal success they are meeting the new conditions imposed.
>
> This change will call for new drawings, new patterns and a great deal of experimental work, in order that theoretical and practical harmony may result. Even the nomenclature may have to be changed. We are now in the habit of speaking of a 12-in., a 24-in., or a 36-in. lathe, at the same time forming a tolerably accurate mental picture of what the machine would look like, inasmuch as the dimensions given have a reflective effect in the general design. In the future, these dimensions will be but secondary or incidental, in the same sense that the length of a bed of a lathe is now secondary or incidental, and the 12-in. lathe may (and properly should) have just as heavy gearing and the same power applied to it, and the same rigidity as the 36-in., with the exception of a proper allowance for the leverage strains. This is because the power to be transmitted to the work and resisted by the tool post will in many cases be the same in all sizes, and there is no logical reason why a lathe of 36-in. swing and a lathe of 12-in. swing should not both be capable of removing the same amount of metal in a given time.
>
> Again, in the past, many tools have been ordered of makers because of the statement made that only 3 HP. was required, whereas some other maker may have said that his tool of the same general dimensions would require 4 HP. This situation has been absolutely reversed, and the tools of the future will be valuable and desirable just in proportion to their capacity of sustaining and successfully transmitting the largest power that can be absorbed by the cutting tool.
>
> It is possible that the machine tool of the future will not be rated by its swing, as in the case of lathes, but will be rated by the amount of metal removed. In other words, the rating may be by the depth of cut and feed at 60 ft. on 0.40% carbon steel in all diameters. Drill presses may be rated by the speed at which a drill of given size will penetrate some standard material.* It is on the basis of the metal removed that the machine tool will have to be designed, and the present ratings of bed or swing or gap will simply indicate the general dimensions of the tool as indicated by the size of the work it

*See also the paper by Prof. John E. Sweet in our issue of Nov. 26, 1903.

*This is done in the American Bridge Co.'s specifications for a drilling machine, quoted in another column.—Ed.

can accommodate. The swing of a lathe will then no more indicate its possibility as a metal remover than will the length of its bed or the color which it is painted.

In a certain sense the rivalry between armor plate and the armor-piercing projectile is being repeated in the struggle between the modern tool steels and the tools upon which they are to be used. For many years the tool was the weaker, and would be burnt or quickly dulled or broken off without any damage being done to the machine itself. Now we have a reverse condition; modern tool steel will stand up to its work while it is relentlessly searching out the weak spots in machine design. With the data and experience already at hand, it is now possible to make a complete analysis of the gearing and even the framing and so modify and strengthen the tool as to make it able to stand the demand and successfully transmit the energy from the motor to the tool post.

LETTERS TO THE EDITOR.

Is There a Vacuum Against the Face of Overtopped Dams?

Sir: Referring to the discussion of the effect of a partial vacuum between the sheet of overflowing water and the face of a submerged dam, I would like to inquire upon what experimental data the fact of the existence of such a vacuum, or partial vacuum, rests. It seems entirely credible as a theory, but has any one ever actually demonstrated experimentally the existence of air pressure below the normal, in such submerged dams, and the degree of partial vacuum found there? Possibly data relating to such experimental work has been published, but the writer does not remember to have seen them. It ought to be possible for some of our hydraulic laboratories to determine, not only the existence of such a vacuum and its magnitude, but to develop the laws relating to it.

Yours very truly, Engineer.

New York City, May 6, 1904.

[In our issue of June 12, 1902, we published a description by Mr. Herbert M. Knight of a dam built across the Quinebaug River near Norwick, Conn., which was designed by Mr. J. Herbert Shedd. This dam has an air supply pipe running in front of the flash boards on the crest of the dam for the purpose of destroying the vacuum, and the following extract from Mr. Knight's article may serve as a partial answer to our correspondent.—Ed.]

One other feature of interest is the introduction of pipes into the end and intermediate piers, where purpose is to supply air on the underside of the sheet of water as it comes over the flashboards and so overcome the vacuum which otherwise would exist on the face of the dam caused by the withdrawal of the air by the water. Frequent tests during the freshets of the winter of 1900-01 were made of these pipes to ascertain their action, and it was found that they would draw in heavy canvas when large quantities of water were flowing over the crest of the dam. By this arrangement the extra pressure on the back of dam due to a vacuum more or less perfect on face is removed.

An Instrument for Subdividing Angles and Squaring Circles.

Sir: For a number of years, while teaching higher mathematics to engineering students, the writer used a device of his own invention for multisecting angles, which might be of interest to the readers of your paper. The instrument is an exact semi-cycloid, the generating circle of which has a radius of two inches.

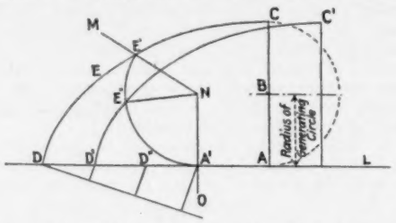
In constructing this semi-cycloid a perfectly circular iron disc of four inches diameter with a hardened steel point on the perimeter was made. An aluminum plate was arranged so as to permit the perfect generation of a complete cycloid upon its surface. The base of this cycloid was bisected by the ordinary methods of geometry and a perpendicular erected to the base at this point, thus forming the outline of an exact half cycloid. The instrument was then carefully cut out from this outline. For class use copies of this were carefully cut from the original pattern.

This instrument, known as the "Hanna Angle Multisector," may be used for dividing an angle or the arc of a circle into any number of equal parts. These divisions are usually made by the draftsman with the ordinary protractor to a sufficient degree of accuracy. However, the angle multisector under discussion has the advantage of being both theoretically and practically correct. Most certainly its mathematical nicety will appeal to the engineer even though its practical application fails to do so.

The method of using the angle multisector is given below, followed by a demonstration of its mathematical correctness.

In the accompanying sketch let M N O be an angle which is to be trisected. Take a radius N A' equal to B A, the radius of the generating circle of the instrument, and describe the arc A' E'. At A' erect the perpendicular D A' L on N A'; place the instrument so that the cycloidal arc D E C shall fall on E' and that D A, the base of the instrument, shall fall on A' L, the vertex D to be within the angle M N O; then trisect the line D A' by the principles of geometry with the oblique line and the system of parallels shown in the figure. Call the points of trisection D' and D''. Keeping the base of the instrument coincident with the line L A', slide it until the vertex of the semi-cycloid coincides with D'. Mark the intersecting point of the cycloidal arc and the circular arc E'' and draw N E''. Then Angle E' N E'' is one-third of Angle M N O, which was the object to be attained.

Proof: The straight line D A' is equal to the circular arc A' E' and the straight line D' A' is likewise equal to the circular arc A' E'' by a well known principle of the cycloid. But D' A' is two-thirds D A' by construction; therefore, the circular arc A' E'' is two-thirds the circular



Trisecting an Angle by the Cycloid.

arc A' E', whence it follows that the circular arc E'' E' is one-third the circular arc A' E'. From this it readily follows by geometry that Angle M N E'' is one-third of Angle M N O.

Had it been desired to divide the given angle into any other number of equal parts the line D A' would have been divided into that number of equal parts and the process continued as above. Had the angle been reflex (greater than 180°) the trisection would have been performed by taking two-thirds of one-half the angle the bisection having been obtained by the usual method.

A semi-cycloidal instrument may be used also, as discovered by the writer, to find a square having an area equivalent to that of a given circle. This may be done in the following manner: Find a fourth proportional to the radius of the generating circle of the cycloid, the base of the semi-cycloid and the radius of the given circle. Upon a line whose length is the sum of this fourth proportional and the radius of the given circle construct a semicircle. At the point in this diameter where the two above-mentioned segments meet erect a perpendicular having its other extremity in the circumference of the semicircle; this will be a side of the required square.

F. W. Hanna,
Asst. Engineer, U. S. Geological Survey.

5330 Ellis Ave., Chicago, Ill., April 9, 1904.

A Diagram for Maximum Shears and Moments from Wheel Loads.

Sir: The accompanying diagrams (Figs. 1 and 2) are graphical representations of bending moments and shears in girders due to engines passing over them.

The diagrams are worked out for two engines, one of which is Cooper's E40 (Fig. 1), while the other (Fig. 2) is for the St. Louis Terminal loading. They were plotted from the actual values computed for girders whose spans are multiples of five feet. For the shear diagram certain intermediate spans were also computed; these spans give critical points on the diagram, and were selected from an inspection of the wheel spacing of the loading diagram.

For deck plate girder spans and for through plate girder spans having trough (continuous) floor, the moments and shears that can be read off directly from the diagrams are all that are usually required.

The diagrams are also applicable to through plate girder spans having stringers and floor beams, where it is desired to obtain the maximum moments at the floor beam connections. If the stringer length is 1/16, 1/8, 1/4 or 1/2 of the span, the moments can be taken directly from the diagram and are accurate. If the stringer length is some other fractional length of the span the following method is used to obtain moments at the desired points: Lay off horizontally to scale the span and the 1/16, 1/8, 3/16, 1/4 and 3/8 and center points, and on vertical lines through these points lay off above to some scale the maximum moments at these points read from the diagram. By joining these plotted points a maximum live load moment diagram of the girder is obtained. The dead load diagram can be laid off below the horizontal line. The maximum moment at any floor beam or any point is then obtained by scaling the total vertical ordinate at that point. The moments thus obtained, while approximate, differ so little from the computed moments that the difference will cause no change in the design of the structure.

The results for any of Cooper's loadings can be obtained by multiplying the values taken from the diagrams of the E40 engine by the proportional factor.

We have found these diagrams very convenient and sufficiently accurate for use in preliminary designs, and especially convenient for checking over work already designed.

Yours truly,
Brenneke & Fay, Civil Engineers.

Fullerton Bldg., St. Louis, Mo., April 14, 1904.

A Convenient Form of Moment Table for Wheel Loads.

Sir: I enclose print of a table for computing bending moments from locomotive wheel-loads on bridges, which I submit to you because of its convenient and compact form. The loads given are for one rail only, one thousand pounds being the unit. The wheel loads are numbered consecutively from left to right and are spaced to scale. The heavy figures above and to the right of the heavy diagonal line show all possible summations of loads that may come on a given span; for example, the sum of loads 2 to 6, inclusive, is 110,000 lbs. The small figures adjacent to the heavy summation figures show the total length of wheel base for all combinations of loads, for example, the length of wheel base of loads 2 to 6 is 15 ft. The large figures below and to the left of the heavy diagonal line show all combinations of summation of moments of the loads, the center of moments being the load on the extreme right; for example, the moment of all the loads 2 to 6 about load 6 is 825,000 ft.-lbs. The small figures adjacent to the heavy moment figures show the po-

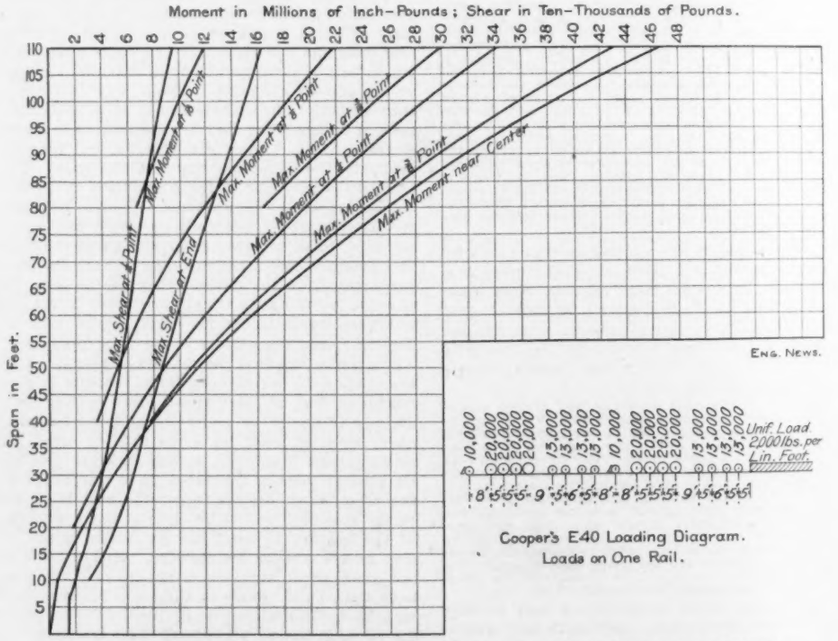

Moment in Millions of Inch-Pounds; Shear in Ten-Thousands of Pounds.
Span in Feet.
Max. Shear at ½ Point
Max. Moment at ½ Point
Max. Shear at End
Max. Moment at ⅜ Point
Max. Moment near Center
ENG. NEWS.
Unif. Load 2000 lbs. per Lin. Foot.
Cooper's E40 Loading Diagram.
Loads on One Rail.

FIG. 1. MAXIMUM MOMENT AND SHEAR DIAGRAM FOR COOPER'S E40 LOADING.

sition of the center of gravity for all combinations of loads; for example, the center of gravity of the loads 2 to 6, inclusive, is 7.5 ft. to the left of load 6.

Yours truly, R. B. Ketchum,
Asst. Engr., Oregon Short Line R. R.

Salt Lake City, Utah, March 29, 1904.

Concerning Grain Bin Pressures and the Theory of Retaining Walls.

Sir: The experiments conducted by Mr. J. A. Jamieson on grain pressures in deep bins and described in Engineering News of March 10, 1904, are of great value. They illustrate the importance of taking into account friction against a wall whether it is the side of a grain bin or a retaining wall. Mr. Jamieson's final method of computing the amount of the grain carried by the bottom of a "deep bin" is probably near enough to the truth for a practical solution. The same may be said of Mr. Janssen's formula, quoted on p. 224 of Engineering News for March 10, 1904.

It must not be overlooked, though, that k = *ratio of lateral to vertical unit pressure at the depth h*, is not a constant as assumed, though experiment shows that it approaches a constant as h increases.

This has but little practical significance in getting *maximum* pressures on the bottom in deep bins filled with grain, but it is vital in the theory of retaining walls, and some observations concerning the actual lateral pressure at small depths may be pertinent.

In Table I. of Mr. Jamieson's article are recounted the pressures found by experiment in a full-size bin, 12 ft. × 13 ft. 6 ins., inside dimensions, and with a depth of 67 ft. 6 ins. The wheat weighed 49.4 lbs. per cu. ft.; its angle of repose was 28° and the coefficient of friction between grain and bin walls was 0.41667, corresponding to an angle of 22° 37′.

On dividing the lateral unit pressure by the vertical unit pressure, for different depths, as given in Table I., we derive the following values of k.

Height of grain.	k.	Height of grain.	k.
3.75 ft.	0.31	18.75 ft.	0.56
7.5 "	0.48	22.5 "	0.58
11.25 "	0.53	30. "	0.59
15. "	0.55	67.5 "	0.596

It is thus seen that k is not constant, but varies from 0.31 for a height of grain only 3.75 ft. to 0.596 for a full bin. The value of k, however, nearly reaches the limit at a height of grain of 30 ft. For greater heights it is practically constant.

That k for small heights of grain could not equal 0.596 is readily seen from the theory of retaining walls backed by an unlimited mass of earth or other granular material. For, with a bin whose cross-section was 12 × 13.5 ft., the pressure on the side walls for a few feet height of grain should agree nearly with the lateral pressure found from a correct earth pressure theory corresponding to an unlimited mass of grain.

Consequently, if experiments were made upon a bin whose cross-section was, say, 20 × 20 ft., the values of k should not reach a maximum for a much greater "height of grain" than for a bin of 10 × 10 ft., or for the small experimental bins whose section was only 1 × 1 ft.

Also as the horizontal dimensions of the bin increased indefinitely the values of k for all heights should approach indefinitely the constant pertaining to a correct retaining wall theory corresponding to an unlimited mass of grain.

The Rankine theory gives, when $\varphi = 28°$,

$$k = \frac{1 - \sin \varphi}{1 + \sin \varphi} = \tan^2\left(45 - \frac{\varphi}{2}\right) = 0.36.$$

This theory ignores the friction between the grain and wall and is thus incorrect. In fact that theory has been thoroughly tested by the writer, using the results of the many experiments that have been made by various authorities on retaining walls and it was long ago abandoned because it did not at all agree with any of the experiments (see Eng. News for March 3, 1898, p. 147, and for May 5, 1898, p. 290, for articles touching this subject by the writer).

When the friction of the grain against the wall is included, the direction of the thrust against the wall is not horizontal, as in the Rankine theory, but inclined to the normal to the wall at the angle $\varphi' = 22° 37'$.

The value of k for this case, is easily shown to be k = 0.2945, or say k = 0.30 (see the writer's "Retaining Walls," p. 96, Van Nostrand's Science Series, No 3).

This value for k is sufficiently near the first value given in the table above (0.31) for a height of grain (in the 12 × 13.5 ft. bin) of 3.75 ft., when the retaining wall theory would naturalv be expected to apply very nearly.

It is gratifying to find that it does.

It is assumed in making out the table above, giving values of k for different heights of grain, that the lateral pressure recorded was that corresponding to the lowest point of the vertical diaphragm or practically at the bottom of the bin, where the corresponding vertical pressure

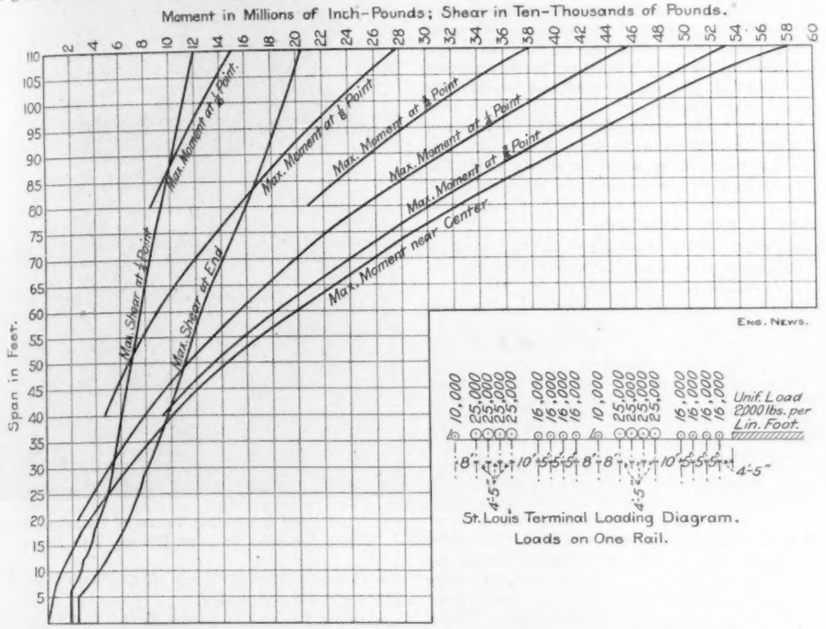
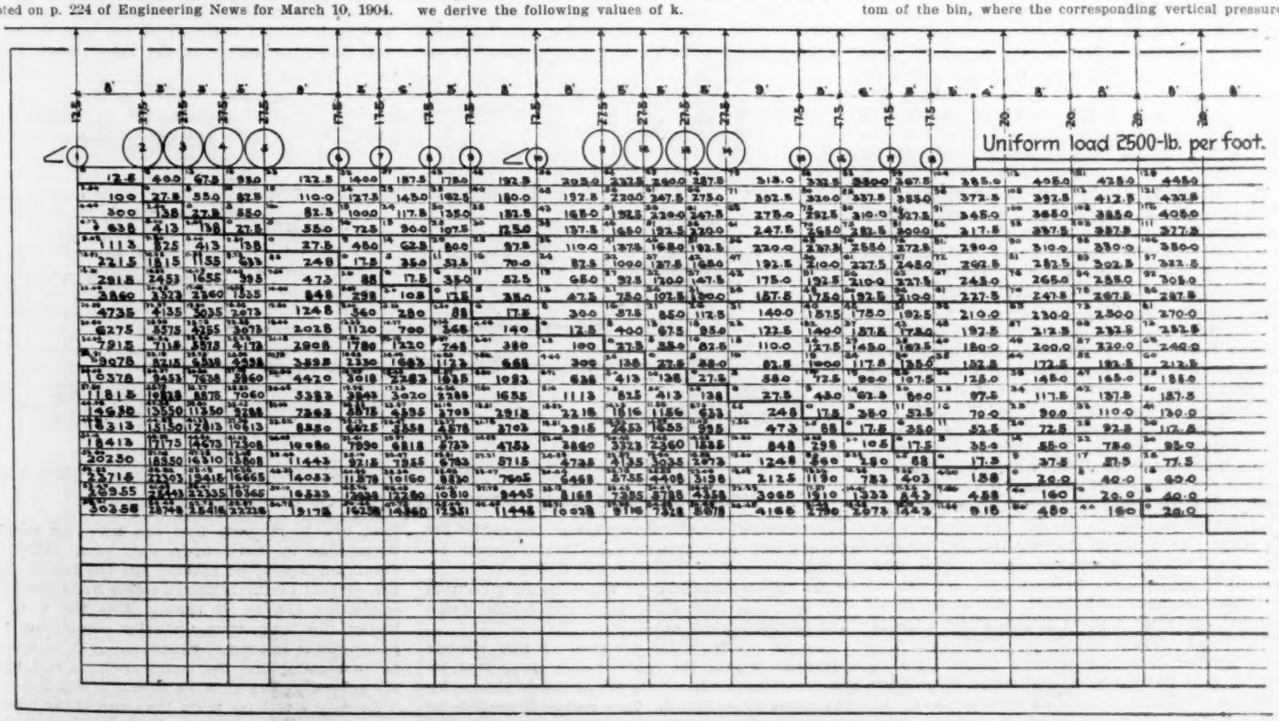


FIG. 2. MAXIMUM MOMENT AND SHEAR DIAGRAM FOR ST. LOUIS TERMINAL LOADING.



A CONVENIENT MOMENT TABLE FOR WHEEL LOADS.

Loads On One Rail.—Heavy figures above and to right of stepped line are summations of loads from stepped line to load at right of column. Small figures with these loads give total wheelbase for each load. Heavy figures below and to left of stepped line give summation of moments for all loads from left-hand edge of column to stepped line, around load over stepped line. Small figures with these moments give distance of center of gravity of these loads from stepped line.

was measured. This is evidently assumed by Mr. Jamieson and it seems correct. For suppose a depth of grain, to begin with, equal to depth of diaphragm. The lateral pressure is evidently greatest at the bottom and this, from the flexibility of the rubber, must be alone recorded by the mercury. If more grain is added, the greatest pressure on any part of the diaphragm is alone recorded as before.

I trust Mr. Jamieson will some day add to our indebtedness to him, by finding the experimental unit pressure in 20 × 20 ft. or even larger bins. Such an investigation would tend to complete the subject for deep bins and if the pressures were recorded say for every 2 ft. additional height of grain for 20 ft. down, it would materially add to our knowledge concerning "earth pressure."

It may be observed in concluding that the maximum value of k as found by experiments on deep bins was found to be for wheat, 0.6. No theoretical determination of this factor has been proposed, so that it must be determined by experiment for each material and for varying dimensions of bins including shallow bins as special cases if the solution is to be complete.

Wm. Cain.

Chapel Hill, N. C., May 2, 1904.

Notes and Queries.

In the article on "Modern Methods of Handling Iron Ore From Minnesota Mines to Pittsburg Furnaces," in our issue of May 5, 1904, the titles under Fig. 9 and Fig. 10 and under Fig. 11 and Fig. 12 were transposed by mistake.

"R. W. M." requests us to repeat his query as to the definition of "gumbo" in earthwork classification, published in our issue of March 24. Will some of our readers in the "gumbo" region of the West, favor us with a description of the material and state wherein it differs from ordinary clay.

In the article on "Studies of Color in Water," published in our issue of April 28, it was stated that the colorimeter used was the invention of Dr. G. C. Whipple and Mr. W. E. Foss. Our attention is called to the fact that this is an error. The joint inventor with Mr. Foss was Mr. Desmond Fitzgerald, Past-President Am. Soc. C. E.

BALANCED CABLE CRANES FOR HANDLING EXCAVATED MATERIAL AT DEVONPORT, ENGLAND, AND ZAMBESI FALLS, SOUTH AFRICA.

Cableways for handling rock were extensively used on the Chicago Main Drainage Canal, but, so far as we know, cableways have never been used on a large scale for removing the material excavated by a steam shovel. In the construction of the great Admiralty Docks at Devonport, as shown in Fig. 2, electric cableways are conveying the material excavated by a steam shovel, and delivering the material directly into scows. These electric cableways, or balanced cable cranes, have a distinctive and meritorious feature (aside from the use of an electric trolley car or motor carriage), namely an oscillating tower loaded with weights which counterbalance the weight of the trolley car and its load, of which more will be said later.

The Admiralty Docks now under construction form in reality an extension of a dock system that has been growing since the building of the first small dock at Plymouth in the days of William the Third. Not until 1898, however, has Devonport constructed anything larger than second or third class cruisers. In that year a modern slip was constructed in which the first-class battleship "Ocean"* was built, since which time other large naval vessels have been launched, including the armored cruiser "Powerful," which is 500 ft. long.

While, as stated, Devonport can turn out vessels 500 ft. long, it can not dock ships of more than 380 ft. in length. The present dock work, which was begun in 1896, will, when finished, make it possible to dock the largest vessels afloat. This dock work involves the construction of (1) a tidal basin opening on the estuary of the river Hamoaze, (2) a closed basin with an entrance lock, and (3) three graving docks. The tidal basin will be 10 acres in area with a depth of 55 ft. and a length of 2,100 ft. The closed basin will have an area of about 40 acres with a depth of 55 ft. and a length of quayage of 4,500 ft. The three graving docks are between the two basins, two of the docks having entrances from both ends, the third dock having an entrance from the closed basin only by means of an entrance lock. This entrance lock may be used also as a graving dock. The three graving docks have a length of 741, 745 and 470 ft., respectively, and the depth of floor below the coping is 48 ft. in two of the docks and 59 ft. in the other one. The docks will be provided with intermediate caissons so that it will be possible to divide the docks into shorter lengths for small vessels.

*The launching of the "Ocean" was described in a paper published on p. 116 of our volume July-December, 1899.

The entire dock work covers an area of about 113 acres, or about double that of the existing dock yards. The greater part of this area was originally a soft mud. Before excavation was begun, cofferdams having a total length of nearly 2¾ miles were built. Piles 85 ft. in length were used in cofferdamming, yet at no place was rock bottom reached. The timber used was Oregon pine imported from Vancouver. The cofferdams were not finished until March, 1899, after two years' work, and in June the work of excavation was begun, contracts being let in three parts: (1) Excavation; (2) dock construction; and (3) construction of an outer sea wall to form a permanent substitute for the cofferdams.

METHODS OF EXCAVATION.—The excavation of the mud amounts to about 5,000,000 cu. yds. When the work was first begun, a staging was built on the seaward side and on this staging a hoisting engine was mounted. On the opposite landward side another hoisting engine was mounted on a traveling staging. By means of these two engines, drag scrapers were operated.* A number of these plants were installed and worked satisfactorily in excavating the surface soil; but they were eventually replaced with steam shovels, dump cars and locomotives. As the excavation increased in depth, the removal of the loaded cars from the pit became a more and more serious problem, so that about a year ago last October one of the Brothers' electric cable cranes, or balanced cable cranes, as they are now called, was installed, and was subjected to working tests that resulted in the installation of three more of these cableways. These were first arranged as shown in Fig. 2; two cross cableways, B and C, of 575 ft. span, remove the 3½-cu. yd. skips as fast as loaded by the steam shovel which has an average output of about 1,000 cu. yds. a day. These skips go to the left dumping directly into scows, as shown in Fig. 2; but for convenience are arranged so as to transfer at A to the two cableways, a and b, having a 1,050-ft. span, and are by them delivered to the dumping hoppers, whence the material slides directly into the boats. When two cableways are supported by one oscillating tower, the cables are jointed and pass around a horizontal sheave located on one of the towers, as at E, Fig. 2.

The two cross-cableways will eventually be used for receiving and delivering concrete for docks and for setting cut stone.

One of the valuable features of this electric cableway is that the cable may be supported by one or more intermediate props, as is shown by the props at A, Fig. 2. This makes it possible to work long spans with short end towers and with very light weight cables. In this particular case, had it not been for the ability to use the intermediate props, the end towers would have had to be very much higher than they were in order that the cables a and b might clear the cables B and C. The props A are mounted on a staging provided with wheels running upon a track, so that when the shovel advances to cut off another ledge, the props are advanced also.

*This work was described in Engineering News of Aug. 24, 1899.

Fig. 1. Inclined Oscillating Tower of Balanced Cable Crane Arranged to Load Directly into Boats.

At the right end of cables B and C, and at the top of the towers, will be seen the houses in which the motor cars are housed at night.

The oscillating tower, or shears, as shown in Fig. 1 is worthy of special mention. In our issue of Nov. 15, 1900, a description of the balanced cable crane was given, but the fact was not clearly brought out that the up and down oscillation of the loaded tower entirely counterbalances the motor car and its load. To illustrate this oscillating action, the three positions of the load in Fig. 3 will serve. A glance at the upper figure would lead one to suppose that the traveling electric motor has to travel up a very steep incline to reach the tower, or shears; but the fact is that the descent of the counterweights hung from the oscillating towers, or shears, does the work of lifting the load, thus virtually eliminating the grade due to the sag of the cable. It is, of course, not necessary that the counterweights rest upon the ground at any time, as shown in Fig. 3, nor is it necessary to have more than one of the towers pivoted so as to oscillate. In fact, the balanced cable cranes shown in Fig. 2, are counterweighted only at one end, the tower at the other end being

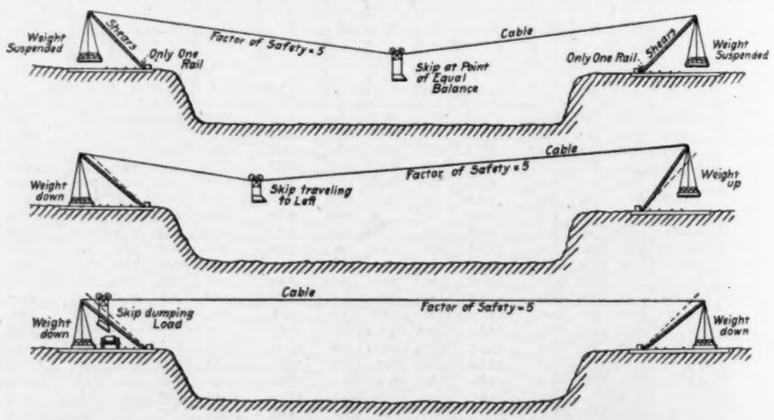


FIG. 3. DIAGRAMS ILLUSTRATING OPERATION OF BALANCED CABLE CRANE.

rigid. It is evident that the oscillation of the tower possesses not a fanciful but an actual value since without such a means of reducing the work of moving the loaded skips, it would be necessary to use both very much heavier motors and very much heavier cable drawn extremely taut. The electric motors on three of these cable cranes are of 60-HP. each, and on the fourth cable crane, which was the first one installed, the motor is 30-HP.

THE ZAMBESI RIVER PLANT.—In connection with the foregoing description of the balanced cable crane as used in the Devonport Dock work, it will be interesting to note briefly the salient features of another plant that is now being installed over the Zambesi River, just below the great Victoria Falls, in Africa.

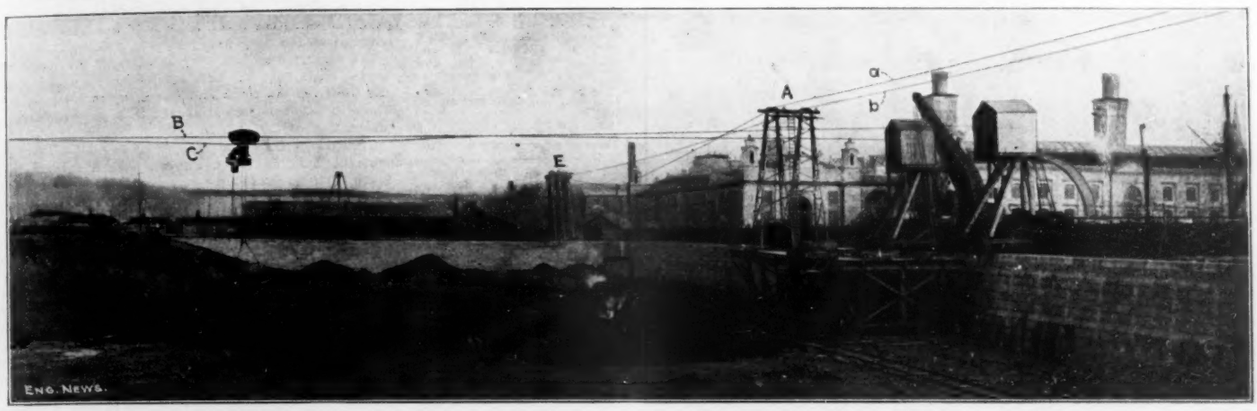


FIG. 2. BALANCED CABLE CRANES CONVEYING EARTH FROM A STEAM SHOVEL, DEVONPORT DOCK WORK.

The Cape to Cairo Railway will eventually cross the Zambesi River where now is being erected this electric cableway; but as some 40,000 tons of railway construction plant must be carried across the river before the erection of the bridge, a cableway of some sort had to be installed. On account of the extreme lightness and effectiveness of the electric cableways used on the Devonport Dock construction, the management of The Cape to Cairo Railway decided to install a balanced cable crane having a span of 870 ft. and a capacity of 10 tons per load. A side elevation of this plant is shown in Fig. 4 (for which we are indebted to "Engineering") where it will be noted that only one of the towers oscillates, the other being rigid. The cable is 2⅝ ins. diam., and as there are no running ropes, nor fall rope carriers, the saving in weight of cables over the ordinary cableway is very marked.

This plant was built and tested in England before shipment. Fig. 5 shows the motor car lifting a 12-ton load, in the test for capacity. All motions of the motor car are under the control of one man who controls the hoisting and traveling mechanism; and, as he is always directly over the load, signal men and other assistants are dispensed with. It is estimated that this plant will convey across the river not less than 800 tons, per working shift.

The inventor of the balanced cable crane is Mr. W. F. Brothers, of 1099 Dean St., Brooklyn, N. Y., and 25 Victoria St., London.

RECENT THREE-CYLINDER COMPOUND LOCOMOTIVES IN EUROPE.

In the article on balanced compound locomotives in our issue of March 17, reference was made to the famous three-cylinder compounds introduced on the London & Northwestern Ry. by Mr. F. W. Webb, who recently retired after long service as Locomotive Superintendent. In a recent number of "The Engineer" (London) we find mention of two new designs of three-cylinder compounds, which are worthy of some attention.

The first is a peculiar machine intended to show that the remarkable speed performances of electric cars on the Berlin-Zossen experimental railway can be duplicated by steam locomotives. The engine is of a 4-4-4 type, with the inside high-pressure cylinder driving the cranked axle of the first drivers, and the outside low-pressure cylinders driving the rear pair of drivers. Coupling rods connect the two pairs of wheels. The tender is mounted on two four-wheel trucks and carries 4,000 gallons of water and 7 tons of coal. The boiler has 3,000 sq. ft. of heating surface and 50 sq. ft. of grate surface. A sheet steel housing outside of the running board encloses the engine and tender and extends in front of the boiler, where it forms a wedge-shaped cab for the driver. The total length is 81 ft. 6 ins.; and the total wheelbase, 68 ft. The engine weighs 79 tons and the tender 57 tons. The engine is intended to haul a trainload of 180 tons at a maintained speed of 80 miles an hour. The general design was suggested by Mr. Wittfeld, of the Prussian Public Works Department, at Berlin; and the details were worked out and the engine built by Henschel & Sohn, of Cassel, Germany. The engine will probably be exhibited at St. Louis.

The Midland Ry. of England has in service five fast passenger engines of the eight-wheel type (4-4-0), on the three-cylinder compound system invented by Mr. Walter J. Smith, of Gateshead, but with modifications introduced by Mr. S. W. Johnson, Locomotive Superintendent, who designed the engine. Mr. Johnson (like Mr. Webb) has recently retired after many years of service. The engines are described as follows:

There are three cylinders, one high pressure and two low pressure. The high-pressure cylinder, which has a diameter of 19 ins., and a stroke of 26 ins., is placed between the frames under the smokebox, and communicates its power to a crank on the driving axle. The low-pressure cylinders are 21 ins. diameter with 26 ins. stroke, and are placed outside the frames on either side of the high-pressure cylinder, and communicate their power to crank pins in the wheels on the axle connected with the high-pressure cylinder. The outside cranks are at right angles to each other, and the middle crank bisects the larger angle between them. The middle cylinder takes steam directly from the boiler at 195 lbs. pressure, and this steam is exhausted without the intervention of any pipe directly into the steam chest common to the two outside cylinders. Simultaneously with the admission of steam to the high-pressure steam chest, steam at a predetermined pressure is automatically admitted to the low-pressure steam chest by a specially constructed regulating valve placed on the side of the smokebox. The regulating valve is so arranged that when the maximum pressure allowed in the low-pressure chests is attained, further supply of steam directly from the boiler is automatically cut off; thus excessive stresses are avoided on the moving parts, and although the boiler pressure is 195 lbs. per sq. in., none of the pistons are ever subjected to a pressure equal to that of the pistons in a simple engine working with a boiler pressure of 170 lbs.

When working compound, the pressure in the low-pressure chests, according to the position of the reversing gear, varies from 40 lbs. to 60 lbs.; but for starting or for working a heavy train up a steep incline, increased power can be obtained by admitting steam from the boiler through the regulating valve to the low-pressure chests for as long a time as is necessary. The amount of steam that can be passed by the regulating valve between the minimum and maximum limits is governed by a controlling valve placed in the cab. By manipulating this valve, the driver can vary the low-pressure steam chest pressure to suit the work in hand. As an instance of this, quoting from the actual indicator diagrams, while working compound at a speed of 10 miles per hour, the indicated horsepower is: High-pressure cylinder, 141; low-pressure cylinders, 198; total, 339 HP. Working semi-compound at the slightly higher speed of 11.5 miles per hour, the other conditions being similar, the indicated horsepower is: High-pressure cylinder, 59; low-pressure cylinders, 596; total, 655 HP. A gage in the cab shows the driver the amount of pressure that the engine is working with in the low-pressure steam chests.

A piston valve is used for distributing steam to the high-pressure cylinder, and D-valves are used for the low-pressure cylinders. Each valve is actuated by means of an ordinary Stephenson link motion, and the reversing gear is so arranged that the high-pressure motion can be moved independently of the low-pressure motion, and one handle will reverse both motions together or separately, as may be necessary. To prevent excessive forward pressure or unnecessary back pressure on the high-pressure piston, which would occur at starting in some positions of the engine, non-return valves are so arranged that steam can pass from the low-pressure steam chest into either end of the high-pressure cylinder. These valves only open when the pressure on one or other side of the high-

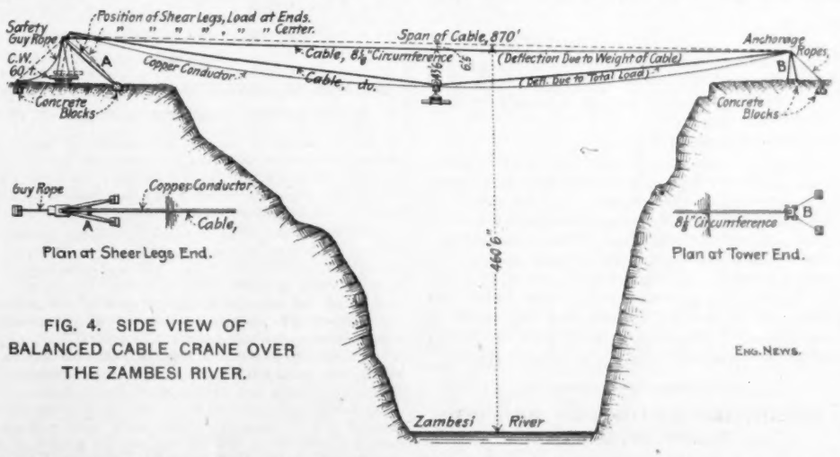


FIG. 4. SIDE VIEW OF BALANCED CABLE CRANE OVER THE ZAMBESI RIVER.

pressure pistons is lower than the pressure in the low-pressure steam chest. The engine has a firebox 8 ft. 6 ins. long and the boiler barrel is 11 ft. 7 ins. in length and 4 ft. 8 ins. in diameter. In the first two engines of the type built, one of the boilers is fitted with plain copper tubes 1¾ ins. inside diameter, and the other is fitted with steel Serve tubes 2¾ ins. outside diameter. In both engines the front portion of the grate is hinged, so

FIG. 5. TESTING ELECTRIC MOTOR OF BALANCED CABLE CRANE WITH 12-TON LOAD.

that it may be lowered, and the fire and clinker remaining in the box at the end of the day's work can then be pushed through into the ashpan.

The principal dimensions are as follows:

Driving wheels (4)	7 ft. 0 ins.
Weight of engine, in working order	133,280 lbs.
Weight of tender, in working order	117,824 "
Cylinders, h-p. (1)	19 × 26 ins.
" l-p. (2)	21 × 26 "
Boiler, diameter	4 ft. 8 "
" length	11 " 7 "
" rail to center	8 " 6 "
Steam pressure	195 lbs.
Heating surface, tubes	1,448 sq. ft.
" " firebox	150 " "
" " total	*1,598 " "
Grate area	26 " "

*With Serve tubes, 1,720 sq. ft.

It may be interesting to note also that the Berlin Metropolitan Ry. has recently had built some three-cylinder simple engines for its suburban trains, in order to give increased acceleration with trains making frequent stops. They are tank engines of the 2-6-2 type, with driving wheels 4 ft. 11 ins. diameter. All the cylinders are 19.68 × 24.8 ins., fitted with piston valves. The boiler has 1,667 sq. ft. of heating surface and 24¾ sq. ft. of grate surface. The weight is 78 tons, with 50½ tons on the driving wheels.

CLASSIFICATION AND INSPECTION RULES FOR YELLOW PINE LUMBER.

The following rules for classifying and inspecting yellow pine lumber were adopted by the Georgia Interstate Saw Mill Association at a meeting held at Jacksonville, Fla., March 15, 1904, and by the South Carolina Lumber Association at a meeting held at Cheraw, S. C., on April 15. The rules are to take effect on July 1 next.

GENERAL RULES.—All lumber must be sound, well manufactured, full to size and saw butted; free from unsound, loose and hollow knots, worm and knot holes; through shakes, or round shakes that show on the surface; square edge, unless otherwise specified. A through shake is hereby defined to be through or connected from side to side, or edge to edge, or side to edge. In the measurement of dressed lumber the width and thickness of the lumber before dressing must be taken; less than one inch thick shall be measured as one inch.

CLASSIFICATION.

FLOORING.—Flooring shall embrace four and five quarter inches in thickness by three to six inches in width. For example: 1 × 3, 4, 5 and 6; 1¼ × 3, 4, 5 and 6.

BOARDS.—Boards shall embrace all thicknesses under 1½ ins. by 7 ins. and up wide, including 1½ ins. in thickness by 7 ins. in width. For example: ¾, 1, 1¼ and 1½ ins. thick by 7 ins. and up, wide.

SCANTLING. — Scantling shall embrace all sizes from 2 to 5 ins. in thickness and 2 to 6 ins. in width. For example: 2 × 2, 2 × 3, 2 × 4, 2 × 5, 2 × 6, 3 × 3, 3 × 4, 3 × 5, 3 × 6, 4 × 4, 4 × 5, 4 × 6, 5 × 5, and 5 × 6.

PLANK.—Plank shall embrace all sizes from 1½ to 6 ins. in thickness, not including 6 ins. × 7 ins. and up in width. For example: 1½, 2, 2½, 3, 3½, 4, 4½, 5, 5½, 5¾, × 7 ins. and up in width.

DIMENSION.—Dimension sizes shall embrace all sizes 6 ins. and up in thickness by 7 ins., and up in width, including 6 × 6. For example: 6 × 6, 6 × 7, 7 × 7, 7 × 8, 8 × 9, and up.

STEPPING. — Stepping shall embrace 1 to 2½ ins. in thickness by 7 ins. and up in width. For example: 1, 1¼, 1½, 2 and 2½ × 7 and up, in width.

ROUGH EDGE OR FLITCH.—Rough edge or Flitch shall embrace all sizes 1 in. and up in thickness by 8 ins. and up in width, sawed on two sides only. For example: 1, 1½, 2, 3, 4, and up thick by 8 ins. and up wide, sawed on two sides only.

INSPECTION.

STANDARD.—All lumber shall be sound, sap no objection. Wane may be allowed one-eighth of the width of the piece measured across face of wane, extending one-fourth the length on one corner or its equivalent on two or more corners.

MERCHANTABLE. — All sizes under 9 ins. shall show heart entire length on one side or edge; sizes 9 ins. and over shall show heart the entire length on two opposite sides. Wane may be allowed one-eighth of the width of the piece measured across face of wane, and extending one-fourth of the length of the piece on one corner or its equivalent on two or more corners.

PRIME.—Scantling shall show heart on two faces the entire length; other sizes shall show two-thirds heart entire length on two opposite sides. On not exceeding 5% of the pieces, wane may be allowed one-eighth of the width of the piece measured across face of wane and extending one-fourth of the length of the piece on one corner or its equivalent on two or more corners.

COLLAPSE OF A BUILDING DURING CONSTRUCTION.*

By H. de B. Parsons,† M. Am. Soc. C. E.

At the request of some of the members of the society the writer presents this brief description of the construction and collapse of the Hotel Darlington, with the object of bringing out a discussion which may lead to improvement in the designs of such buildings.

CONSTRUCTION.—The building was being erected on lots known as Nos. 50 and 50½ West 46th St., Borough of Manhattan, City of New York. The land measured about 55 ft. in width by 100 ft. 5 ins. in depth. On the east and west sides the adjacent buildings were of the ordinary construction for residences—of brick with brownstone fronts, four stories and basement in height.

The Hotel Darlington, as the new structure was to be called, was being constructed on the "cage" system, that is, all the weight was supported on the columns.

The outside walls were of brick, and partly concealed the exterior row of columns. These walls were continuous from the foundation, and did not rest on girders at the floor levels.

The columns were of cast-iron, with end flanges, and with side brackets and lugs cast near the top to carry the girders. All the columns were of rectangular section, generally varying from 9 ins. square by 1 in. thick, in the basement, to 6 ins. square by ¾-in. thick on the upper floors. Each column had top and bottom flanges cast only on the north and south sides, and each flange had two bolts. Fig. 1 illustrates a typical column. The thickness varied with the column position in the building. Some of the 9-in. columns in the basement were ⅞-in. in thickness. Fig. 2 illustrates a typical column foundation.

The girders and floor beams* were of steel. The girders, generally, ran east and west across the building. They were supported on the brackets cast on the columns, and were bolted to the lugs with two bolts at each end. The beams, generally, ran north and south, and were riveted to the girders by double-clip angles with two or three bolts through each leg of the angles. The floor members were all of rolled sections—I's and channels—and many were marked "Phœnix" and "Carnegie."

The floor arches were of cinder concrete, laid up on the Roebling system. The spans were variable, averaging from 4 ft. 6 ins. to more than 5 ft. The thickness of the arches could not be determined, as all of them were destroyed.

The building was to have been twelve stories and a basement in height, with a penthouse, or one-story structure, partly covering the roof. Each floor was lettered, and the columns on the same floor varied in size.

The construction had progressed until the metal work for the ninth floor had been erected complete, and some of the work for the tenth and eleventh floors was in place. The structure collapsed at about 1.30 p. m., on Wednesday, March 2, 1904.

OBSERVATIONS ON THE WRECKAGE.—On collapsing, the building fell downward with a leaning to the north, that is, toward the rear. As viewed from a sixth-story window in the Hotel Patterson, situated immediately in the rear on 47th St., the "center of fall," toward which all the various members pointed, more or less, was a little to the west of the center line of the building and a little to the north of a line drawn between the rear walls of the adjacent buildings, Nos. 57 and 61 West 46th St. Practically all the material fell inward, except a relatively small amount, which fell over the rear wall against and into the Hotel Patterson.

The columns in the outer walls broke off, with approximate uniformity, between the second and third floors, although the floor systems of the stories below, and the interior columns (except some in the basement) were carried away, leaving the outer columns standing, from their foundations to the points of rupture. See Fig. 3.

The columns were measured with calipers and showed a fair uniformity as to thickness of metal on opposite sides. The variation was about ⅛-in. or less.

In the great majority of cases the columns broke at the flanges, leaving one or both of the broken flanges bolted to the corresponding flange of the adjacent story column. A few of the columns were broken at or near the center.

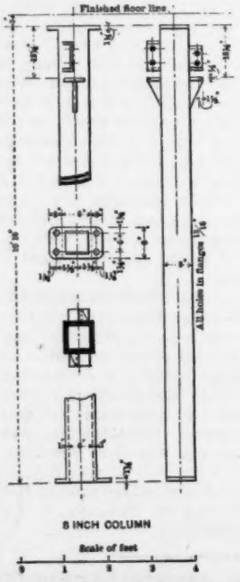


Fig. 1. Typical Column of Darlington Building.

There were no ribs cast on, to stiffen the flanges.

The column ends were faced. No shims were found between the ends of the columns.

The holes in the column flanges were drilled, 13/16 and ⅞-in. in diameter. The bolts were ¾-in., and some were loose. The holes in the lugs for the girders were cast, and were about ⅞-in. in diameter. The holes in the girders were about ⅞-in. in diameter. The bolts were ¾-in.

The fractures in the body of the cast-iron columns exhibited fairly good metal. The fractures at the flanges exhibited blow-holes and honey-combing in many instances. About 15% of the flanges were honeycombed, about 25% were defective, and about 60% were fair to good. The defects did not show on the exterior surfaces. The flanges varied from 1 in. to 1¼ ins. in thickness.

The rolled-steel members of the floor system were twisted. The steel gave evidence of being good material, and the bolts held well. A number of pieces—I's and channels—were taken from the debris, which, from the appearance of the bolt holes, had never been erected. Such pieces were marked for use on the 10th, 11th and 12th floors. They were found chiefly on top of the ruins and near the rear. On March 6 about 22 unerected pieces were taken out during the morning. The weight of

*Reprinted from the "Proceedings of the American Society of Civil Engineers," of April, 1904 (p 382). To be presented before the society May 18, 1904.

†22 William St., New York City.

*A typical floor-plan of the Darlington Building, and a sample column schedule, were given in Engineering News of March 10, 1904.

this unerected material was between two and three tons. Also, a broken piece of an 11th-story column (M 32), which had been erected, was taken out with them.

The concrete from the floor arches was broken, and few lumps larger than 12 × 12 ins. were found.

The foundations under the exterior and interior columns were found true and level. The cast-iron shoes under the columns were in place and unbroken. The soil under the column foundations was clay in every instance where dug up, both at the front and back of the lot. The foundations had an area of about 10 ft. square, or amply sufficient to have sustained the load intended.

Three hoisting engines and boilers were dug out of the debris comparatively slightly injured. Their boilers were intact.

All members were bolted. Rivets were not used. There were no diagonal braces, corner braces, or any special means used to provide lateral stiffness against wind or side pressure. The columns were held in their vertical positions by the floor systems resting on the bearing brackets.

CAUSE OF FALL.—The bolts fastening the girders and beams against the column lugs were of smaller diameter than the holes, so that the columns received little or no lateral support. The column lengths were bolted together at top and bottom, and acted as continuous columns. All the loads were eccentrically supported on the side brackets. The columns were too long to carry the superimposed weight. One column situated at or near the "center of fall" (previously described) broke. The upper part of this column, being deprived of its support, fell and pulled with it the floor members bolted to it. Each of these floor members pulled over the adjacent columns to which the other ends were attached; and these columns, having no lateral support, broke at the lower flange, as the pull had a lever arm of about 10 ft., or the length of the column. The above-described action and reaction of the stresses affected only those portions of the structure above the level of the original fracture.

In falling, the mass of material from above crushed down and broke that part of the structure below the level of the original fracture.

The exterior columns did not break off as low down as the interior columns, because the mass fell away and did not crush them as it crushed the interior ones. The uniformity in height at which the exterior columns broke indicates strongly that the primary fracture occurred at or about the level of the fourth floor.

As proof that the top fell into and toward the "center of fall" before the lower part of the structure collapsed, columns G 11 and K 11 were taken out of the debris near the "center of fall" and from beneath other members which originally were connected at points lower down in the building. Near the same spot, column D 36 was found standing in a nearly upright position. Of these columns,

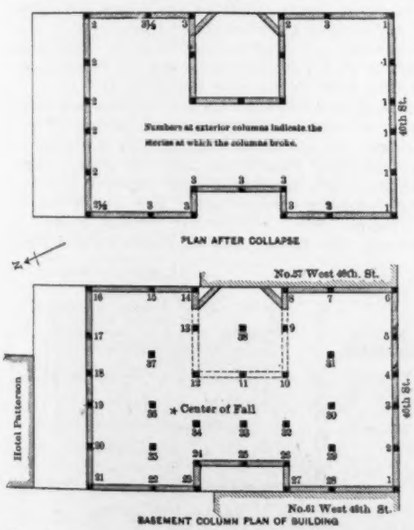

Numbers at exterior columns indicate the stories at which the columns broke.
PLAN AFTER COLLAPSE
No. 57 West 46th. St.
Center of Fall
Hotel Patterson
46th St.
No. 61 West 46th St.
BASEMENT COLUMN PLAN OF BUILDING

Fig. 3. Column Plan, and Effect of Collapse on Wall-Columns.

the first was broken at the center, and the other two at the flanges.

Furthermore, as more of the structure was south of the "center of fall" than north of it, the northern or rear portion was forced outward against the Hotel Patterson. This action is illustrated in Fig. 5.

As proof that the original break did not occur on the uppermost story, the unerected material and the derrick mast and boom were found on top of the mass of debris.

The structure collapsed because of lack of lateral support for the story columns, permitting them to act as continuous columns having a ratio of length to least radius of gyration in excess of the known limits of safety.

SPECIFICATIONS FOR MACHINE TOOLS.

A subject which has come up for consideration by several technical societies within the past year is that of the improvement of machine tools, and one particular feature of the subject is the question as to how far the design and manufacture of the machine should be covered by the purchaser's specifications, and how far these matters should be left to the maker. In ordinary cases, the sales

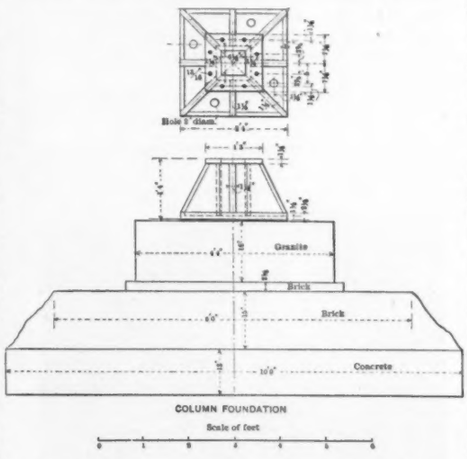


Fig. 2. Typical Column Foundation, Darlington Building.

of machine tools are rarely based upon specifications as to materials, fittings and workmanship, but are largely governed by the price, the reputation of the maker, and the eloquence of the salesman. Where the purchasers are large firms or where specially important machines are required, of course the above conditions do not obtain, and the purchaser is more or less exacting as to the design and construction of the machine.

On the Pennsylvania R. R. the tools to be purchased for shop equipment are selected by the Superintendents of Motive Power of the several grand divisions. From Mr. R. N. Durborow, Superintendent of Motive Power at Altoona, Pa., we learn that machines are frequently purchased on specifications as to the work which they are to accomplish, leaving to the builders (as a rule) the choice of materials and design. The officials noted sometimes have ideas of their own concerning design, which they discuss with the builders, with the result that they are sometimes incorporated in a machine of more or less special design. It has been incorrectly reported that this road has a standing committee of machine tool experts which meets periodically, but while this is not the case, it is true that the design and working conditions of the machines are discussed by the foremen as well as by the higher mechanical officials. Mr. Durborow writes us:

> The foremen of our various departments are called into consultation by the master mechanic, assistant master mechanic, and assistant engineer of motive power, in the discussion of new tools, and we quite frequently call upon the manufacturer to design something special for us when we have definite ideas as to what is wanted.

Some time ago this road purchased an unusually heavy wheel lathe, which was designed by the Niles Tool Works, but embodied a good many suggestions from the officers of the mechanical department. The specifications required that the speed should be variable over a wide range, which was accomplished by means of change gears on projecting studs so as to give a cutting speed of 10 to 30 ft. per minute on any tire within the range of the machine, which was from 50 to 62 ins. diameter on the tread. In addition, a pair of magnetic clutches was built in such a way as to reduce the cutting speed (by introducing a worm gear) to about 4 ins. per minute, so that the tool could cut out hard spots without damage to itself. This lathe is driven by a 25-HP. electric motor, and pressures of 40,000 lbs. at each of the tools have been obtained.

The following specification for a planing machine illustrates the practice of the Pennsylvania R. R., and it will be noted that this specifies the thrust on the table with a given belt pull and cutting speed:

Pennsylvania R. R.: Specifications for Planer 48 ins. × 48 ins. × 12 ft.; 4 heads; parallel drive.

Beds.—To have vertical surface just inside of Vs to prevent side movement. Bed finished on bottom. Shafts to run in bronze boxes.

Table.—To have three longitudinal slots for 1¼-in. bolts, finished 1 3-16 ins. wide. Metal over head of bolt, 2 ins. Also four rows of short slots 10 ins. long for 1-in. bolts. One row inside and one row outside of outer longitudinal slots.

Gearing.—To be calculated by Lewis formulas, and to give a thrust on table (at safe working load) of 20,000 lbs. with belt pull of 60 lbs. per in. of width and cutting 50 ft. per minute. Return, 75 ft. or more per minute, with backing belt running 5,000 ft. per minute.

Side Heads.—Finished for use of square in setting up work.

Heads.—On cross rail to have two set screws each, bearing on gibs to set firmly in position.

Feeds.—1-32-in. to ¾-in. on top heads. 1-32-in. to ¼-in. on side heads.

Rail.—Raised and lowered by power.

The practice of the American Bridge Co. in purchasing machine tools is as follows: When the machines to be ordered are of thoroughly standard design, the specifications are drawn so as to cover all points on which improvement is desired and embodying features in standard machines of which the company's engineers approve. In cases where the machines are not so decidedly standard as to be covered by the type of specifications just described, the engineers enter into details to a greater extent and define more exactly what is required. In these, although considerable detail is entered into, some latitude is left to the bidder. When machines are not standard, but the designs are prepared by the company's engineers, the specifications (of which complete working drawings form a part) go to considerable length in defining necessary details of construction, finish, materials, etc. When alternative bids are asked for in the case of standard machines, bidders are required to submit descriptions sufficiently detailed to cover all important points.

An example of the practice of the American Bridge Co. is afforded by the following abstract of specifications drawn up for an engine lathe specially equipped for boring bridge pins:

> These specifications intend a heavy, rigidly-constructed screw cutting engine lathe, embracing latest improvements, including taper-turning attachment and compound rest. The design and workmanship shall be first-class and the machine competent to meet the most advanced demands of the best modern shop practice.
>
> The drilling of axial holes from 1¼ to 3¼ ins. diameter through bridge pins 8 to 18 ins. diameter by 42 to 96 ins. long, and counter boring and tapping the ends 4, 6, 8 or

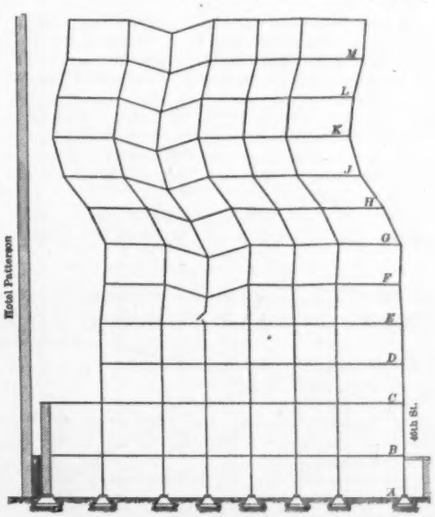


Fig. 4. Diagram Illustrating Manner of Collapse; Vertical Section North and South through Darlington Building.

10 ins. diameter, 3 ins. deep (6 per in.) forming an important part of the work for which the machine is designed, and its general character depending largely upon the requirements of this demand, proposals under these specifications will clearly state the swing and bed length of the tool offered.

The drills, counterbore and taps may be mounted on the lathe carriage or on a special slide. Convenient steady rests of rigid construction will be provided for guiding the drill into the work and for supporting the pin.

A continuous feed of not less than 4 ft. 6 ins. will be required for drilling, and there shall be preparation made for using the lead screw in tapping. The machine shall be capable of maintaining indefinitely a feed of not less than 1 in. per minute, with a 2-in. drill in 0.40% carbon

steel; holes larger or smaller being produced at rates ranging according to size. There will be furnished a 2-in. oil-feeding drilling tool, suitable for this work to a depth of 4 ft. 6 ins. Convenient preparation shall be made for mounting, dismounting and securely holding the drills, counterbores, taps, etc.

Other than drilling as before specified, it is intended that the machine shall have capacity for the economic and convenient performance of all kinds of general lathe work within its scope, and due consideration will be given to the use of the new high-speed tool steels under heavy cuts and feeds. All proposals will state the maximum depth of cut the machine can carry in 0.40% carbon steel at 40 ft. and 60 ft. per minute, with a feed of 1-16-in. per revolution of lathe spindle.

It is intended that while the machine shall be capable of carrying a cut at 60 ft. per minute as specified, the gear ratio between the motor and first driver shall be on the basis of 40 ft. per minute, but with necessary preparation to readily increase to 60 ft. if desired.

All drives shall be through gearing, which must run smoothly and quietly. No chain drives to be used.

Steel shall not be made to bear on steel in rubbing contact. All wearing parts and bearings to be of dimensions sufficient to avoid vibration, and to be so amply provided with means of lubrication that undue heating may not arise when the machine is working continuously and performing the maximum duty. All exposed gears shall be properly guarded.

Builders so desiring may tender alternate bids for such standard machines as they may be prepared to offer, provided that such tenders shall give full and complete description of the machine and its capacity, noting particularly its scope, comparative with the requirements of the machine designed by these specifications.

Another specification by the same company for heads for gantry drills specifies the character of the materials as follows:

All material shall be of a high standard, and all iron castings shall conform to the requirements of the specifications of the company. Steel forgings shall not contain over 0.06% of phosphorus, and shall contain the following percentage of carbon: Spindles, 0.8%; set screws, 0.7%; all other forgings, 0.25 to 0.30%. The miter gears and bevel pinions shall be of the highest grade of phosphor bronze.

For the ordinary classes of machine tools, however, the purchase is usually made on the basis of work required to be accomplished. On the part of the salesman or agent, much is made of the work which a machine can do, and of its advantages in point of compactness or weight, but little is said (except in the most general way) as to the details of construction, strength of parts, or the quality of material used. This latter point is frequently overlooked altogether, and in certain cases the omission may enable a machine to be built which is of practically the same design and construction as another machine, but at considerably less cost, owing to the use of inferior grades of material. In ordinary practice, also, the questions of design, material and workmanship are left entirely in the hands of the manufacturer.

For the assistance of both purchaser and salesmen, most manufacturers issue attractive illustrations of their machine, accompanied by general descriptions, but no comparison of two or more of these descriptions will give any clear idea as to the relative merits of the machines. To illustrate this point, we print below extracts from letters received from several machine-tool manufacturers, replying to requests for information as to their specifications:

(1) We have complete detail drawings for all standard machines that we build, but do not have any general drawing or specifications. They are not required in order to sell our machines, and we do not even send out blue prints except for some special appliance for special work to go on a regular machine. All we furnish is a photograph and a statement as to weight, capacity, number and kinds of tools, size of gears, speed and horse-power required.

(2) We make quotation only upon receipt of statement as to the largest hole and thickest material to be punched, the heaviest plate or bar to be sheared, and the throat depth wanted, so that we can judge of the work to be done and select a machine of suitable size.

(3) We issue illustrations with partial descriptions attached, giving an idea of the machines offered, but without much detail information.

(4) We have no specifications for machine tools. The buyer generally specifies what he wants, and we come as near to it as we can with our regular line of machines.

Probably the most complete specifications for machine tools are those which have been prepared by the Navy Department and the War Department in the purchase of tools for the Government shops. Since these tools have to be purchased through public advertisement and award of the contract to the lowest bidder, it is necessary for the protection of the Government that the specification shall describe exactly what the bidder is to make and furnish.

With the growing appreciation of the importance of high quality in machine tools, there is reason to believe that the practice of buying machine tools on detail specifications will increase. It should be no more difficult to draw a specification for a lathe than for a locomotive, and a punch can be as exactly described as a bridge. Such care by purchasers will tend to raise the standard of machine tool construction and to the expenditure of money on up-to-date design and excellence of workmanship that now goes to pay salaries and traveling expenses of salesmen.

Fig. 1. View of Concrete-Steel Arch Bridge Over the Kalamazoo River at Plainwell, Mich.

A CONCRETE-STEEL HIGHWAY BRIDGE AT PLAINWELL, MICH.

By P. A. Courtright, C. E.*

The village of Plainwell is situated in Gun Plains Township, Allegan County, Michigan, and is on the Kalamazoo River. On the old plank road from Kalamazoo to Grand Rapids was constructed the first wooden bridge across the river at Plainwell, in the early 50's. This was carried away by the ice in 1876. It was rebuilt, and again destroyed in 1881. The next effort was a wooden truss bridge, with spans about 20 ft. long, resting on pile foundations. In November, 1902, one of the bents at the north end of the bridge collapsed, and it was decided to build a steel, or concrete-steel bridge. An act was passed by the Legislature of 1903, granting the township the right to issue bonds for $20,000 for the purpose of building a new bridge, carrying Main St. over the river. In February, 1903, the township board advertised for sealed bids on a steel and concrete-steel bridge, 414 ft. between abutments, with 18-ft. roadway and two 5-ft. sidewalks. The writer's connection with the work began March 19, when the bids were returnable.

*Marshall, Mich.

There were 23 proposals submitted for different types of steel bridges, varying in price from $14,000 to $26,000; all the leading builders in the country being represented. For concrete-steel construction, six bids were received; ranging from $16,000 to $27,000. The Board favored a concrete bridge, but the only bid within the appropriation was rejected on account of faulty design.

It was evident that the volume of work must be reduced to compass the desire for such a bridge, and it was decided to reduce the width 5 ft. by leaving off one sidewalk. The letting was adjourned to April 10, and a new call issued for bids upon a concrete-steel bridge, 414 ft. long between abutments, with 18-ft. roadway, and one 5-ft. sidewalk. Bidders were required to furnish their own plans, as the law in Michigan does not accord to the township board the right to receive bids upon a plan prepared by them. At the adjourned letting, three bids were received, varying from $19,900 to $20,500. The contract was awarded to the O. A. Slater Construction Co., Limited, of Pontiac, Mich., for $19,900. Their plan was for a bridge 446 ft. long over all, with seven arches of 54 ft. opening and 8 ft. rise. Work was begun on May 4, 1903, and the bridge was completed on Nov. 2. Fig. 1 is a view of the completed bridge, and Fig. 2 shows the proportions of the arches, etc.

Conditions for construction were very favorable. The water varied in depth from 3 to 5 ft., with a current of two to three miles per hour. Under the silt and sand which formed the river bed, gravel was found to a depth of about 3 ft.; below this was encountered quicksand, filled with stones of varying sizes. For foundations, piles were driven to an approximate depth of 10 ft. below the bed of the stream. Cofferdams were built, the water pumped out, and the excavation carried down until 1 ft. of gravel was left above the quicksand. The piles were sawed off 18 ins. above the bottom of the excavation, and the concrete carried up to the springing line of the arches. There were 200 piles driven, and 16 of the old piles coming inside of the foundations were found in such a perfect state of preservation, that they were sawed off and left in place. Piles were driven until the penetration did not exceed ½-in with a 2,000-lb. hammer falling 30 ft.

The gravel and sand for the concrete was taken from a bank near the north approach of the bridge. It was of an exceptionally fine quality; entirely free from loam, clay or other foreign matter. The specification for concrete provided the following proportions: For arches above springing line: 1 Portland cement, 2 sand, 4 gravel. For foundations of abutments and piers below springing line: 1 Portland cement, 3 sand, 6 gravel. For spandrel and parapet walls: 1 Portland cement, 3 sand, 7 gravel. Owing to the natural mixture of the sand and gravel in the pit, it was decided to change these proportions by making the foundations 1 cement to 8 sand and gravel; arches and spandrel walls, 1 cement to 6 sand and gravel. The parapet wall being light, and over 400 ft. in length, it was strengthened by making the proportion 1 cement to 4 sand and gravel. The proportions were determined by measure; the wagon beds being built to hold a

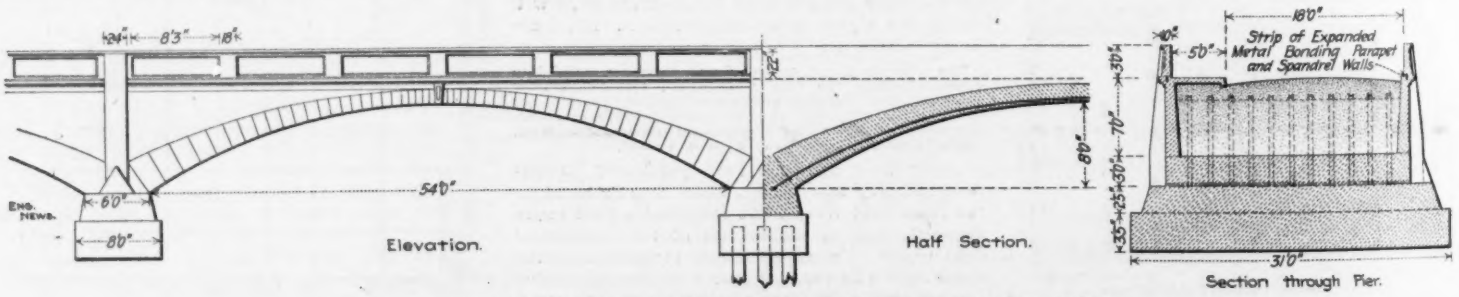


FIG. 2. DETAILS OF CONCRETE-STEEL ARCH BRIDGE AT PLAINWELL, MICH.
P. A. Courtright, Marshall, Mich., Engineer for Township Board; O. A. Slater Construction Co., Pontiac, Mich., Contractor.

cubic yard of gravel; a sack of cement was taken as 1 cu. ft. For foundations, the gravel was used without screening; stones over 4 ins. diameter being thrown out at the pit or on the mixing board. For the arches and spandrel walls, the gravel was passed over a screen having a 2-in mesh, used on the wagon. The material for parapet walls was screened to 1-in. largest dimension.

Fig. 3. McKelvey Concrete Mixer at the Plainwell Bridge.

The concrete was mixed with a McKelvey continuous mixer, shown in Fig. 3, and by the methods employed a more complete blending of material would be difficult to produce. The gravel was loaded upon wagons in the pit, and hauled to a platform at the intake of the mixer. Half of the cement required in the concrete was spread over the surface of the load, and the whole was dumped through the bottom of the wagon bed, spread with shovels, and the balance of cement added. One man shoveled the material over and passed it to another who shoveled it into the mixer. The construction of the mixer is such that the material is turned over eight times in passing through it. After one-third of the distance had been passed, water was added in sufficient quantity to produce the required consistency. The mixer delivered the concrete direct into wheel-barrows, from which it was dumped into place upon the work. The concrete was spread in layers of from 2 to 4 ins. in thickness, and thoroughly rammed with iron tamps; two men were employed tamping for each man shoveling.

The cement used was of the Wolverine brand, manufactured by the Wolverine Portland Cement Co., of Quincy, Mich., and from the tests made, showed remarkable strength. Tests from one car, are given below:

Test for fineness:	
Passing No. 50 sieve	100.0%
Passing No. 80 sieve	96.7%
Passing No. 100 sieve	92.6%
Test for activity:	
Initial set	2 hours
Final set	2¾ hours
Test for soundness by boiling	O. K.
Test for tensile strength:	
Neat cement, 7 days	712, 732 and 826 lbs.
Neat cement, 28 days	848, 883, 869 and 949 lbs.
6 gravel, 1 cement, 7 days	168, 182, 187 and 193 lbs.

The gravel test given above was made from clean sharp gravel, passed through a screen of 3-16-in. mesh, all sand having been removed. The gravel tested showed 32% of voids, which would seem to bear out the statement that it was of an exceptionally fine quality. Several other tests were made with the same gravel, and showed a tensile strength of from 175 lbs. to 205 lbs. per sq. in.

In the construction of the abutments and piers, the faces were set back 6 ins. at a point 2 ft. below the springing line of the arches, this affords an unyielding foundation for carrying the heels of the centers. The piers were built up to the springing line. The concrete was leveled, and a form put on, setting 1 ft. back from the faces, and extending the entire length of the pier; this was carried up 2 ft. to form a backing for the arch rings. The forms for the pilaster foundations and points and heels of piers were put on later, and this part of the work completed before the arch rings and spandrel wall construction began.

In constructing the arches, the generally accepted plan of building in longitudinal sections was adopted. Each arch was built in three sections; one section constituting a day's work. Work was begun at the heels of the arches, and carried over as nearly equal at all points as possible. After completion, the upper surfaces of the arches, and a belt of 6 ins. on the spandrel walls, were covered with a 1-in. waterproof coat. At the line of union between the spandrel and parapet walls, expanded metal was used as a safeguard against cracking.

Owing to the length of the bridge, and the fact that the only way of caring for the water which would naturally come to the roadway was to provide ample drainage, the system of drains in Fig. 4 was designed, and gives entire satisfaction. The fill between arches, up to the subgrade of road was made with alternate layers of sand, clay and gravel, thoroughly compacted with iron tamps. The subgrade was made to conform to the contour of the finished roadbed, and a layer of 1 ft. of gravel and surface earth, mixed and rolled, was added to complete the work.

The following will serve as a basis for estimating the general cost where the actual price of material is not given:

1,490 cu. yds. concrete	@	$7.00	$10,430
1,200 cu. yds. fill	@	.30	360
36,000 lbs. of steel	@	.05	1,800
2,800 ft. piling	@	.20	560
2,230 sq ft. cement walk	@	.10	223

Excavating, pumping, cofferdams and centers were estimated at $791 per arch, or $5,537 in all. This makes a total of $18,910. This amount is somewhat in excess of the actual cost of the work, but would be a safe estimate for general purposes. The cost of concrete given above was estimated upon the assumption that gravel would have to be bought by the load, and hauled a considerable distance. Fortunately, it was found in sufficient quantities within a few rods of the work, which reduced the price of concrete very materially. The following is a fair estimate of the cost of concrete:

Concrete placed per day (ave.)	30 cu. yds.
Average daily crew:	
13 men, $1.80	$23.40
Engine and mixer	5.00
Foreman	3.00
Team	3.00
Total	$34.40
Per cu. yd	1.14
Material required:	
26 cu yds. gravel, 50 cts	$13.00
19½ bbls. cement, $2	39.00
Total	$52.00
Per cu. yd	1.73
Total cost of concrete in place	2.87

The centers were designed as in Fig. 5. The heels were supported on the benches constructed upon each pier and abutment foundation, and each center was supported at the panel points by 12 temporary piles. These were driven in advance of the foundation work, capped with timbers, and used as a working platform. The centers were made of Georgia pine plank. Each rib section was built up with three planks; two 2 × 12 ins. for outside, and one 2 × 10 ins. between. These were securely nailed and bolted together, the panels being joined by bolting on two pieces of 2 × 4-in. oak, as shown. The top chord was made of one plank, cut in sections, and rounded to fit the intrados of the arch. The panel points were supported upon 8 × 12-in. timbers carried on posts resting on 8 × 12-in. timber caps on piles.

The wedges for lowering the centers were used at all bearing points; and the centers were brought into position with these wedges. They were set with the level, so that the upper surface of the lagging was ¼-in. above normal elevation. Observations showed a settlement of about ¼-in. in the center during construction. The centers were covered with 2 × 12-in. planed pine lagging, making a very rigid and smooth surface for concrete. There seems to have been no settlement in the arches after the removal of the centers. The minimum of time allowed for the removal of centers after the completion of an arch was 28 days; three of them were left for a much longer period, owing to delays.

The appearance of the arch rings, with voussoir joints, was produced by nailing half-round strips on the form, and gives a good effect to the work. The entire structure was built in the forms, with the exception of the 14 keystones which, owing to their peculiar design, were cast separately, and set in the form.

The steel used in the arches consisted of 4-in. 6-lb. channels, bent to a radius of 70 ft. and spaced 1.9 ft. c. to c. Where joining was necessary, the splices were made by riveting straps on the sides and bottoms of the channels, 16 rivets ½-in. diameter being used in each splice. The ribs were secured at the heels to transverse 5-in. angles embedded in the concrete. The ribs were set in place over the centers, and brought to their proper position by wooden struts of the required length to keep the rib at the correct distance from the lagging. Eight of these struts were used to each rib. The ribs were held firmly in place by wires passed over them, down through the lagging and around a support below the center. These wires were used at all points where the rib was supported. In constructing the arches, the concrete was driven under the ribs by means of a special tamping tool until the bearing was taken off the struts, after which these were removed.

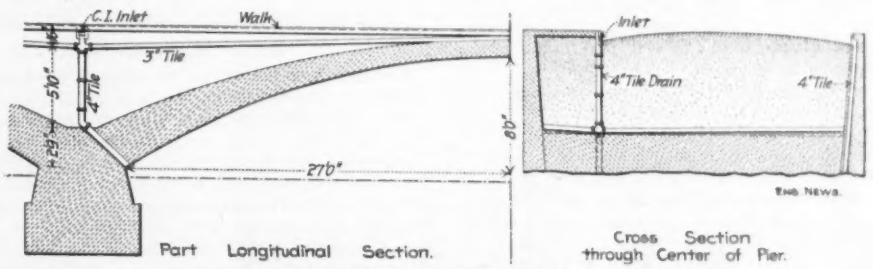


FIG. 4. ARRANGEMENT OF DRAINS IN BRIDGE.

Owing to the fact that sufficient space could not be obtained within the wall forms to use a facing of fine material in advance of the regular composition, the entire stock for the walls was screened much finer than that for foundations and arches, and care was exercised to keep stones away from the forms. The appearance of the entire surface of the work is uniform, and only slightly granulated. Such places as were broken by removal of forms, were restored by using a mixture of 1 cement and 2 sand, applied with trowels. The entire surface of the walls and arch rings was finally treated with a coat composed of 1 part cement and 2 parts sand spread with brushes.

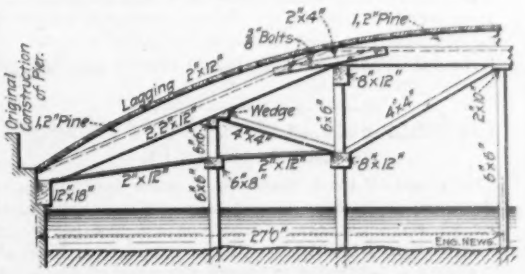


Fig. 5. Centering for Concrete-Steel Arch Bridge at Plainwell, Mich.

Each abutment foundation has 31 piles, and each pier has 23. The piles were oak, elm, beech,

and hickory, not less than 12 ins. nor more than 16 ins. at the head. They cost delivered on the ground and sharpened ready for driving, 15 cts. per lin. ft. The average number driven per day was 8½. The pile driver was of the ordinary type, with leads 30 ft. long, and hammer weighing 2,000 lbs. The engine was an American hoisting engine of 12-HP., supplied with steam from a vertical boiler on the engine bed.

The character of the soil rendered driving very difficult; a penetration of 2 or 3 ins. when starting a pile was the exception rather than the rule. The cost of pile driving per day was as follows: Engine and pile driver, $5; engineman, $2.50; fireman, $1.80; four driver men at $1.80, $7.20. Total, $16.50.

The distribution of concrete in the different parts of the bridge is approximately as follows:

Foundations,	570 cu. yds.	1,154.25	tons.
Arches,	770 " "	1,559.25	"
Walls,	150 " "	303.75	"
Total weight of concrete		3,017.25	"
" " " steel		18	"
" " " earth fill		1,944	"
" " " bridge		4,979.25	"
Load per sq. ft. on foundations		4.20	"
Dead load per sq. ft. on arches		420	lbs.

The design of the arches is the segmental form, and was submitted by the contractors. As stated above, the Michigan law does not give to the township board the right to have a plan prepared, and receive bids upon the same. When the writer was called upon the work, there was no time to prepare plans, or make suggestions in regard to their design. The contract was awarded to the lowest bidder, and while the plan presented was not in accordance with the best practice, it is not objectionable in a general way.

The segmental arch for concrete construction is not by any means an economical design. In the case of a short span where the arch approaches a semicircular form, it requires a greater volume of concrete, and presents an awkward and ungainly appearance. The arch should be designed to meet the requirements of the conditions surrounding it. But where there is neither time nor opportunity to do this, the engineer has often to use designs which are distasteful to him. The longer the span, the nearer the segmental arch can be made to approach the theoretical form, without special design. If the rise of the arch can be kept down to a minimum, the difference between the segmental and theoretical forms will not be painfully apparent.

Corporations and municipalities are alive to the fact that for a moderate advance over the cost of a steel bridge, they can build one of concrete-steel which will increase in strength as it advances in age, reduce the expense of maintenance to a minimum, be more pleasing to the eye, and be better from any point of view. The steel bridge, while of less first cost, is a constant source of expense from repairs needed, and is continually growing weaker from corrosion.

A PROPOSED MACADAM PAVEMENT ON A CONCRETE FOUNDATION, ATHENS, PA.

In England there have been some macadam pavements laid upon concrete foundations, but so far as we know such a combination has never been tried in this country. The cross-section, Fig. 1, shows a pavement proposed for part of Main St., Athens, Pa., as designed by Mr. N. F. Walker, Engineer. It will be noted that the concrete base is to be 6 ins. thick and the macadam 4 ins. thick. The specifications call for a gravel concrete made of Portland cement, the proportions being 1-2-6; and it is specified that after the concrete has been rammed in place, and before it has begun to set, a layer of broken stone or gravel shall be sprinkled over the green concrete and rammed lightly, so as to partly embed the stone. Thus it is intended to bind the concrete to the macadam.

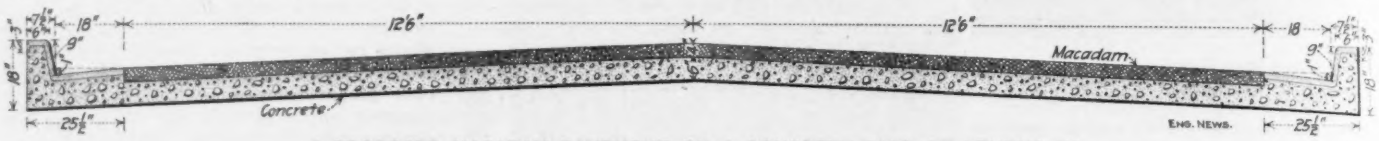
The macadam is to be of limestone laid in three layers: first, a 2½-in. course of 1 to 2-in. stone; second, a 1-in. course of ½ to 1-in. stone; third, a ½-in. course of screenings, dust up to ½-in. stone. After the first two courses are spread they are to be sprinkled and rolled with a 5-ton roller.

Since practically all published data as to compression of loose stone under the roller are based upon rolling either with a light horse roller or a very heavy steam roller, it would be interesting to know what the compression will be under the conditions, particularly since none of the stone will be driven into the subgrade, as usually occurs when macadam is laid directly on the earth.

There were seven bidders on this proposed pavement, three of whom submitted bids on the macadam and concrete combined as follows: $1.14, $1.12 and $0.99 per sq. yd. The remaining four bids were as follows, per sq. yd.:

Concrete	$0.80	$0.65	$1.18	$0.60
Macadam	0.36	0.56	0.55	.40
Total	1.16	1.21	1.73	1.00

The bids on the excavation, curb, etc., were given under "Contract Prices" in the Construction News Supplement of our last week's issue. It will be observed that the average bidding price on this proposed pavement of macadam or concrete is practically one-half the bidding price on a brick pavement on concrete. It will also be observed that the lowest bidder offers to lay the concrete at precisely the same price per cubic yard as the macadam, namely, $3.60.



A PROPOSED MACADAM PAVEMENT ON A CONCRETE BASE, AT ATHENS, PA.

RAILWAY LOCATION IN VICTORIA, AUSTRALIA.

By D. M. Fraser.*

The object of the following paper is to show the practical application of the late A. M. Wellington's admirable work on Railway Location and to attempt to arrive at such modifications of his theories as are in accordance with the conditions prevailing, at present, in Victoria, Australia. I propose to go through his book, chapter by chapter, and to point out what portions may be neglected as applying to conditions not met with here, what portions may be applied in a modified degree and what may be regarded as axiomatic to the science of railway location under any conditions.

Introduction.

The general argument is that errors and incompetency in connection with railway location are less observable by the average mind than the errors in constructive design, for the reason that the latter errors lead to personal or direct monetary disaster while the former lead only to more or less unnecessary annual expenditure in working and maintenance, but which, if capitalized, would appear infinitely more disastrous than the mere collapse of a structure.

Part I.—Economic Premises.

Nearly the whole of this portion of the work applies to conditions which do not exist here—viz., the construction and control of railways by private and competing companies.

In Victoria the general order in which railway projects are initiated and brought to a head is as follows:

The demand for a railway proceeds from an agitation on the part of the local inhabitants and property owners who bring their claims under notice by deputations or petitions to the Minister of Railways. The Minister then receives a report from the engineering authority as to the feasibility of the project, the probable cost of alternative routes and the nature of the traffic.

If it appears from this report that the project has fair prospects, the minister gives authority for a detail survey, trial or permanent, to arrive at an estimate, as closely as possible, of the cost of the line; also the Railways Commissioner is asked to provide a report on the probable traffic and the financial prospects. When this has been done the project is either hung up or else is submitted to Parliament for reference to the Parliamentary Standing Committee on Railways.

The Standing Committee then visit the district and take evidence on oath from the local people as to the resources, physical features, etc., of the country. They also examine the engineering and traffic authorities as to their estimates and the comparative merits of alternative routes.

After taking evidence and having personally examined the country the committee either recommend or condemn the proposal. If the report of the committee be favorable, a railway construction bill is brought before Parliament for final adoption or rejection.

(At present it is compulsory, in the case of country railways, that the land should be purchased by a local trust and handed over, free of cost, to the Government, but as this point does not affect the purpose of this paper, it is not necessary to go into details.)

In his reports to the minister as to the merits of any railway project, the engineering authorities usually point out how the proposed line will fit in with a general scheme of railway extension in the interests of the State as a whole. This aspect of the railway question is very important and should never be lost sight of.

The duty which falls to the engineers in the above process is usually to provide data for the proper consideration by the minister and the P. S. Committee of the relative merits of alternative routes, which will serve, more or less, the district which is asking for railway communication.

This duty comes under the head of "Reconnaissance," that is the gaining of a thorough knowledge of the topography and natural resources of the whole district; the natural direction of traffic to business centers; whether the produce is required for export or for consumption further up country; the population to be served and to what extent the population is likely to increase and all other information which will facilitate the deciding of the route from a railway-finance (or, what is still more important, the national) point of view.

In obtaining a detailed report of the above it is important that the reconnaissance or exploration survey be conducted by one responsible engineer, so that any approximate estimates as to cost may be consistent, even though they be not accurate. The accuracy will depend upon the "personal equation" of the engineer. The most consistent method of arriving at a rough estimate of different routes is to classify the difficulty of the lines under three or four headings, such as, easy, moderately easy, difficult and very difficult, and to apportion to each class of country so much per mile for cost of construction. The practice of making a guess of so much per mile of the whole route is very likely to lead to serious errors and inconsistencies. In specially rough places requiring tunnels or exceptional bridges, bulk sums should be added to the estimate first made.

It will generally be found that the cost of one line out of three or four will be much the least, and that the traffic to be gained on this or another line will be much the greatest so that the problem may be easily reduced to one or perhaps two routes.

It will be necessary to have a detail survey made of the adopted route or probably of two routes, so that accurate estimates of cost, working expenses and probable traffic may be arrived at. Estimates based on mere inspection should not be used for deciding the fate of any line unless the country is so easy that the cost of earthworks, bridges and culverts can be determined within a small amount—say £200 a mile.

A great portion of this Part I of Wellington is profitable reading, even though the conditions of railway economy treated of do not apply here.

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Chapters I. and II. deal only with the American Railway Corporation, as such, i. e., business concerns looking for business in the projection of new lines of railway.

Chapters III. and IV., deal with the nature and volume of traffic and the law of growth therein mostly from a competitive standpoint, but there are many points which should be noted as of advantage in connection with railways under any conditions, especially the emphasis that is placed on the importance of locating lines in such a manner as to produce the maximum traffic or, in other words, the maximum development of the country.

Chapter V. deals with operating expenses and sums up with statement that "the estimate is to be corrected in each individual case according to local circumstances—nothing will fully take the place of intelligent examination of the facts on neighboring roads" (lines in similar country with a similar nature of traffic).

We have our own reports and statistics available here.

Part II.—The Minor Details of Alinement.

Chapter VI. deals with the nature and relative importance of the minor details of alinement—distance, curvature, rise-and-fall.

The arguments and deductions in this chapter are of general application to railway location anywhere, and should therefore be carefully studied before applying the factors which will be now dealt with.

Wellington's factors must be modified to suit our circumstances, as he works on the basis of 6% to 8% interest on capital and the running of general traffic seven days a week. Our railway capital may be taken at 4%, and the running of traffic six days per week.

CHAPTER VII.—DISTANCE.

This factor is treated by Wellington mostly as affecting competitive traffic, but the methods he uses for arriving at the proper valuation of distance may be applied in Victoria, from a national point of view, as it is clearly reasonable that some check should be placed on unnecessary increase of distance on any projected railway, for the general benefit and welfare of the community. Some would argue that increased length means increased revenue; but it should be borne in mind that the increased length will involve increased working expenses (in some degree) and that whatever increases the cost of getting the produce of the people to their market decreases the producing value of their property. Thus unnecessary increase of distance tends to decrease the benefits, the conferring of which is the object of the railways run by the State.

The factors arrived at by Wellington are generally agreed with by other authorities on railway location (see Engineering News, April 20, 1899, and The Railroad Gazette, Dec. 23, 1898). It only remains for us to apply them in a rational manner to our circumstances. The factor to be used depends upon the cost of track maintenance and working expenses of a certain number of trains per day.

For Victorian railways the factor works out approximately as follows:

Up to 20 chains (¼ mile)	£20 ($100) per chain.
" 1 mile	£25 ($125) "
" 3 miles	£30 ($150) "

For Two Daily Trains (return trip) On Any Gage.

The factor per chain is variable according to the increased distance, so, in order to avoid "jumps" in the valuations, the results are best shown by diagram, q. v.

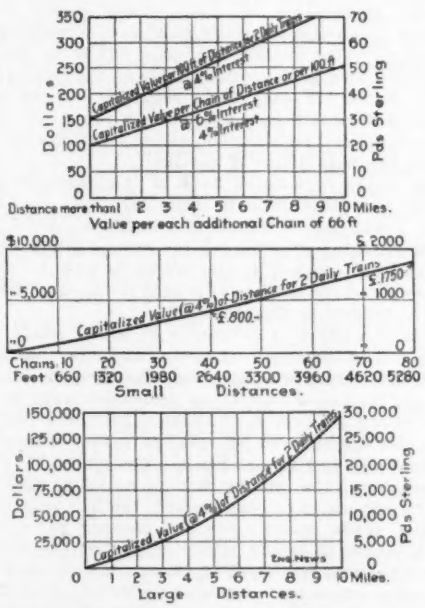
N. B.—Changes in location involving considerable differences in distance are generally decided in Victoria by other than engineering authorities who, however, provide estimates of cost, working expenses, and value of traffic. Indeed it can very seldom occur that large differences in distance in alternative lines exist without larger considerations coming in which render the use of a theoretical factor unnecessary.

The factors for small differences of distance in detail location have only from one-fifth to one-seventh of the effect of the factor for curvature in fixing the location of mountain or hilly lines, so that it is really of not much importance what valuation is adopted within reasonable limits.

In easy country the factor for distance comes in as a set-off against the severance of property, and, in some cases, length of bridges; but in nearly every case the factor for curvature will predominate.

Also it will be found that the total possible difference in distance between a line located for cheapness without regard to minor increases in length and a line run fairly straight between main points is very slight in comparison with total length. It will vary from 3 to 5 chains per mile (4 to 6%) in detail location, where the two types of locations are on the same general route and of the same ruling grade. The difference in amount of curvature, however, may vary 100% between a line run regardless of curvature and a line run with a reasonable factor to reduce curvature. This is the result of actual experience and agrees with Wellington's experience (see p. 584), as to excess curvature.

This predominance of the curvature must not be used as an argument against using the factor for



Diagrams Showing Permissible Expenditure to Save Distance in Railway Location.

distance but simply shows that it is useless to spend much mental effort in trying to fix what ought to be the exact value of the factor for distance—a value which is, in nearly all cases, indeterminate.

Nevertheless cases will occasionally occur where the factor for distance will be fairly determinate and of importance in deciding route.

CHAPTER VIII.—CURVATURE.

The valuation for the curvature factor is more determinate than that of any other factor used in location and the cost of construction is influenced very much more by the curvature factor than by any other factor.

Working out Wellington's factor to suit our conditions we get £4 = $20 per degree* of central angle for 2 daily trains—standard gage.

Other authorities, after independent investigation, agree very closely with Wellington, so that this factor may be used with confidence in every case on open road. It can only be neglected in the design of stations.

In traveling over lines in other States it is very apparent that excessive curvature has the most detrimental effect on the speed and wear-and-tear of rolling stock. Many cases of obviously excessive curvature may be noted and large amounts of money have been spent in reducing the amount and sharpness of the curvature, viz., in New South Wales, New Zealand and Queensland.

In Victoria, so far, there is not much excessive curvature to be observed as the opportunity has not occurred, there being, as yet, no standard gage mountain lines in the State. On the other hand there are cases where economy could have been reasonably effected by the introduction of more and sharper curvature on some pioneer lines. The object of using the curvature factor is to obviate serious errors in either direction. Of course it must be recognized that, when a pioneer line has developed a large and increasing traffic, the fact of money being expended to reduce curvature is not necessarily an evidence of faulty location in the original line.

Wellington and other authorities are agreed that the factor per degree of curvature is to be taken at the same figure, whatever the radius.

As to the sharpest curves that may be adopted in location, Wellington strongly argues that the radius which best suits the general topography of the country should be adopted (especially in pioneer lines) and that the rolling stock should be constructed to suit the curves. This is subject, of course, to the limits of mechanical construction of the locomotive. The adoption of very sharp radii would limit the possibility of making engines of sufficient power.

The question of the sharpest radius can only be settled by noting the experience in other countries where railways have been constructed under similar conditions. See Wellington's table No. 116, p. 325, showing sharpest curves in regular use in the United States.

It seems reasonable to conclude that if the use of a certain minimum radius limits, to a great extent, the amount of curvature that can be used to lessen cost of construction—then a sharper radius should be tried so that the amount of curvature may be governed by the use of the curvature factor and not by the adoption, arbitrarily, of a definite radius; i. e., it should be *possible* (though not *economical*) to put in more curvature than the curvature factor allows.

The sharpest curve at present in use in Victoria is 8 chains radius (= 11°) on the 5 ft. 3 in. gage and 2 chains radius (= 43°) on the 2 ft. 6 in. gage. The adoption of curves of 5 chains (= 16½°) on the 5 ft. 3 in. gage has been proposed, and estimates have been made on surveys having a large proportion of curves of that radius, but so far (April, 1903) the sharpest radius in use is 8 chains (= 11°).

The curvature factor for narrow gage (2 ft. 6 ins.) may be taken at two-thirds that adopted for 5 ft. 3 in. gage—£2⅔ per degree for 2 daily trains (= $13).

It is now the practice to put in transition curves. The spiral curve has been adopted for this purpose. It is not necessary to have a length of straight track between reverse curves where efficient transition curves have been put in.

The elements of spiral curves will be given in tabular form at the end.

CHAPTER IX.—RISE AND FALL.

By averaging the results arrived at by different authorities (Wellington, Engineering News, April 20, 1899, and The Railroad Gazette, Dec. 23, 1898), who agree very closely we get the following values per vertical foot.

	For 2 daily trains.
Minor grades (less than 50 ft. rise) (1%)	£3.10 ($17.50)
Grades steeper than 1 in 100 and flatter than 1 in 50 (less than 50 ft. rise) (2%)	10 (50.00)
Ditto (with more than 50 ft. rise) (2%)	20 (100.00)
Grades steeper than 1 in 50 with more than 50 ft. rise	30 (150.00)

The total value for a certain number of feet of rise and fall can best be shown by diagram q. v.

The highest value must be used per foot of rise and fall when the effect of momentum ceases or when from any cause the momentum cannot be relied on, such as a sharp curve at the foot of a grade, starting out of a station or any other cause. In location such detrimental circumstances should be avoided if possible. In short, the values to be given to rise and fall should be based on the virtual grade the theory of which is fully treated by Wellington.*

The question of rise and fall is very important as, after construction, it cannot be appreciably reduced without great expense, perhaps involving deviations of the original line.

Vertical curves are now used at changes of grade. The method of arriving at the proper curves will be treated at the end.

*Throughout this article the degree of curves is given for 100-ft. chords, although radii are given in chains.

*(See in this connection Prof. Taylor's paper in Engineering News of April 28, 1904.—Ed.)

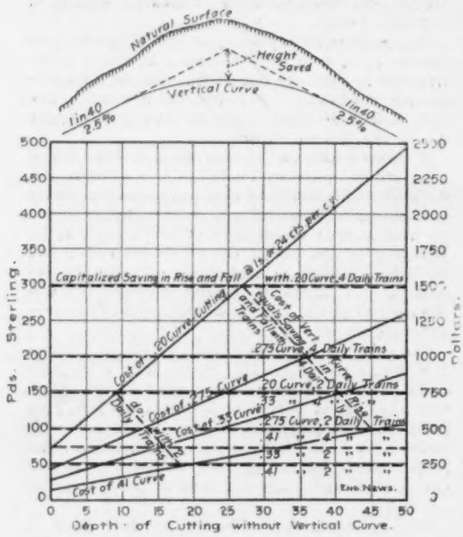
This ends the consideration of the "Minor details of alinement."

Before a permanent survey is started, all the larger considerations such as general route, ruling grade, and sharpest curve will have been settled, so that it is these minor details which will affect the final location of the line.

These factors should be used in settling every detail—the amount of curvature at each individual curve—every break of gradient—and at every place on the route where a possible alterrative is apparent.

These factors can only be used for comparing alternative routes when the different lines to be compared have been laid out with equal skill.

On trial (or preliminary) surveys it will not be necessary to apply the factors in each individual case, but the inexperienced engineer should try their effect in a few cases, so as to get a fair idea what style of line to run as to amount of curvature, so that estimate based on the trial survey may allow enough to construct a truly economical and sensible line on the permanent survey, (or final location).



Diagrams Showing Permissible Expenditure to Reduce Grades.

Part III.—Limiting Gradients and Curvature.

CHAPTER X.—THE RELATIVE IMPORTANCE OF GRADIENTS.

This chapter shows by an assumed and extreme case that the question of ruling gradient is of far greater importance than the question of distance, curvature, and rise-and-fall considered separately and collectively.

The arguments adduced in this chapter are general and apply to railway location anywhere.

CHAPTER XI.—THE LOCOMOTIVE ENGINE.—CHAPTER XII.—ROLLING STOCK. CHAPTER XIII.—TRAIN RESISTANCE.

These three chapters deal with the design and mechanical efficiency of the locomotive and with rolling stock and train resistance, matters which have not a direct bearing on location but are of importance to the subjects dealt with in the succeeding chapters on the effect of grades on train load, operating expenses, etc.

CHAPTER XIV.—THE EFFECT OF GRADES ON TRAIN LOADS.

This chapter gives the method for arriving at the train loads on any grade, with tables and diagrams illustrating maximum loads for locomotives in daily service in the United States.

In comparing the effects of different ruling grades in Victoria we must take into account the class of engine to be used on the particular line under consideration, applying the general principles laid down by Wellington.

All information as to the tractive power and the working loads of our engines is available in our railway department.

The question of reducing the multiplicity of types of locomotives in use here is now engaging attention. Consolidation engines are being introduced giving a much higher tractive power than that of our former most powerful engine ("Y" class) which is six-coupled, without truck, and unsuitable for going round sharp curves.

Our narrow gage engines are of the American type, simple and compound, and are well adapted for the work they have to do.

CHAPTER XV.—THE EFFECT OF TRAIN LOAD ON OPERATING EXPENSES.

(1) The cost of increasing the weight of engines.

(2) The cost of increasing the number of engines to haul the same traffic.

(3) Estimated value per daily train of avoiding an addition 0.1% to the rate of any ruling grade.

These matters are dealt with exhaustively and apply to conditions prevailing here but are of more serious importance in connection with lines of considerable traffic and with the improvement of existing lines.

In the extension of our system it will very seldom occur that the prospective traffic will warrant large expenditure to obtain easier grades than those obtainable naturally on the route which will best serve the district, but cases will occur where alternative grades are obtainable on the same general route. In such cases separate surveys and estimates should be made on each route and that route should be adopted which is estimated to give the best financial results.

It is the imperative duty of the engineer—his most important duty—to make sure that the easiest grade has been tried and fully considered.

In speaking of obtaining the easiest grade, only the grade opposed to the traffic is meant. The question of the balance of grades for unequal traffic is treated in Chapter XVII.

(4) The effect of difference in ruling grade on the cost of distance, curvature, and rise-and-fall.

As the values of the factors depend on the number of trains per day, these values will vary with the ruling grade, i. e., the easier the ruling grade, the less money need be spent to reduce distance, curvature, and rise-and-fall. Therefore, if the character of the country on both routes be similar as to difficulties of construction, the line with the easier grade would come out cheaper per mile. This condition would rarely occur but the point should not be lost sight of, though it only applies in cases where the volume of traffic would be the same on either route.

Wellington concludes, Par. 743.

(1) When the company is or soon may be poor, take the line of lowest first cost.
(2) When immunity from financial embarrassment is assured, take the line which offers the most promising conditions for future growth of traffic.
(3) Only when the two lines are substantially equal in both these respects enter into such minute calculations as these, and whichever line be selected no serious harm can then result.

With our low rate of interest for railway capital and considering that each extension, however small its initial traffic, is part of one national system and a feeder to the main lines, the line (2) should be adopted "which offers the most promising conditions for future growth of traffic."

Par. 744 is of great importance.

Some of the worst sacrifices of gradients are made without effecting any saving in cost whatever, simply from inattention to its importance, or from attaching exaggerated importance to losses of distance or curvature, or from insufficient study of the topography, leading to a too hasty conclusion that all has been done which can be done, when in fact a very little more study would lead to far better results.

Out of a hundred men putting a line through either easy or difficult country, but *especially through easy* country, the writer's observation is that all but four or five of them will adopt rates of grade from ten to fifty or even a hundred per cent. higher than the other five will obtain at the same cost; and the same holds true as to amount of curvature.

But, it may be added, if the location be entrusted to men having the capacity to do their work intelligently and thoroughly, applying the principles laid down by Wellington exhaustively and conscientiously, doing the work for the work's sake—there need be little fear of serious errors.

It has come within my experience that there are men who would rather chop wood for a day than think for an hour. Such men should be left to their natural vocation.

Look thoroughly into matters, and let not the peculiar quality or intrinsic value of anything escape you.—Mar. Aur. Book VI. 3.

CHAPTER XVI.—ASSISTANT ENGINES.

This question only applies where there is a large traffic with constant loads for long distances and need very seldom be considered in laying out new lines in Victoria. It would require consideration in the improvement of old lines. It is an important question and should be well studied when the occasion requires.

CHAPTER XVII.—THE BALANCE OF GRADES FOR UNEQUAL TRAFFIC.

Par. 797 argues that "great economy may sometimes be effected in construction by utilizing to the full such increases of grade as are legitimately made possible by the difference in resistance due to the lighter load in one direction."

This principle has been recognized in the laying out of some recently constructed lines in Victoria and great economies have been effected thereby in cost of construction and in saving of distance. The principle has also been acted on in regrading old lines.

Wellington's Table 185 shows the proper adjustment of grades for unequal volumes of traffic in opposite directions. It will be noted that the proportion of the grades (per cent.) is by no means in the reciprocal ratio of the return freight.

The gross weight of engine, cars, and load in one direction must be compared with the similar gross weight in the opposite direction. The question must be carefully studied in each individual case and estimates made of what would be saved by the adoption of steeper grades for the return traffic, while not omitting the more important question of estimating whether a reasonable increase of expenditure will not enable us to ease the grades for loaded trains in the other direction.

CHAPTER XVIII.—LIMITING CURVATURE AND COMPENSATION THEREFOR.

This chapter deals with the compensation of grades on curves. This principle is very important and is applicable to railway location everywhere.

In fact uncompensated curvature simply means an unreasonable increase of ruling grade. The neglect of curve compensation would tend to nullify the efforts that have been made to get the easiest ruling grades.

Wellington concludes that .05 ft. per degree of curvature (100 ft. chords) is generally sufficient, though where speed is necessarily slow the compensation should be up to .10 ft. per degree. Where curves largely predominate the compensation should be ample. The rate of compensation should be uniform per degree for all curves and not made greater for sharper curves.

For our slightly wider gage (5 ft. 3 ins.) and less pliable rolling stock the compensation should certainly be higher than for American rolling stock.

For example, taking .07 ft. per degree the compensation will work out as shown in the accompanying table (taking the compensation at .035 ft. on the 2-ft. 6-in. gage).

Table of Compensation for Curvature on Railways of Different Gage.

Radius, 5 ft. 3 ins. gage.	Compensation ft. per chain of 66 ft.	Radius, 2 ft. 6 ins. gage.	Grade with 1 in 40 on straight (= 2.5%) 5 ft. 3 in. gage and 2 ft. 6 in. gage, ft. per chain (of 66 ft.)	
4 chains.	1.02	2 chains.	.63	
5 "	.82	2½ "	.83	
6 "	.67	3 "	.98	
7 "	.58	3½ "	1.07	
8 " (= 11°)	.51*	4 "	(1.71%) 1.14	
9 "	.46	4½ "	1.19	Though the compensation required is variable it should not, in any case, be less than two-thirds of this amount. The compensation already on some of our lines is not sufficient.
10 "	.41	5 "	1.24	
12 "	.34	6 "	1.31	
15 "	.27	7½ "	1.38	
20 "	.20	10 "	1.45	
25 "	.17	12½ "	1.48	
30 "	.14	15 "	1.51	
40 "	.10	20 "	1.55	
Straight.	.00	Straight.	1.65 — 1 in 40.	

* = .77 per 100'.

CHAPTER XIX.—THE LIMIT OF MAXIMUM CURVATURE.

This chapter treats of the sharpest radius permissible on railways, and in what way it would limit the train load. The whole of the reasoning applies to railway location anywhere. Wellington concludes, par. 864, that the inherent cost of sharp curvature per train mile is independent of the radius.

He summarizes, par. 879:

(1) "That there is rarely (although there is sometimes) real difficulty in using engines of any desired power, of types approximate for efficient service, on any probable alinement, and (par. 285) that on curves easier than 9 chains or 7 chains radius (10 or 12°) there is no difficulty whatever."

(2) "That those railways are the exception (although they do exist) on which any probable loss of time from the necessity of slowing at sharp curves will be a matter of much financial importance, and that the gain in this respect by any modification of curvature ordinarily possible is much less than is supposed."

(3) "That all danger of limiting effect upon the weight of trains from sharp curvature, within limits specified in Table 188, can ordinarily be avoided and that these limits afford sufficient range for using curves which best fit the ground under all ordinary topographical conditions."

(4) "That the difference in danger of accident which is liable to result from any modifications of curvature ordinarily possible is too small for estimation, as an element justifying additional expenditure."

(5) "That the effect of any difference in radius on the expenses due to wear and tear and consumption of fuel per train-mile, the degrees of central angle remaining the same, is probably either nil or in favor of sharper radii; but that whether this be so or not (par. 252) is a question which should be allowed no weight whatever in fixing a limit of radius."

(6) "That the effect of shorter radii, if they have any, to lengthen the line or increase the degrees of central angle, or both, through the different location which naturally results, is likewise a matter which does not directly affect the question, although it often may indirectly."

(7) "That the natural tendency of inexperienced engineers is to go to extremes in the matter of curvature, either in spending too much money to obtain easy curvature, or, when convinced that this is impolitic, going to the other extreme, introducing recklessly more and sharper curvature than there is any real necessity for; in both cases failing alike to perceive and utilize to the utmost the topographical possibilities."

Also read par. 881 to 886 which argue against fixing arbitrary limits to the radius and caution us against going to extremes in either direction as to easy or sharp curvature.

Here, with our double buffers, the question of buffer locking must be considered in connection with the adoption of sharper radii. Very sharp curves would require the adoption of special rolling stock or the modification of our ordinary stock to obviate this danger.

CHAPTER XX.—THE CHOICE OF GRADIENTS AND DEVICES FOR REDUCING THEM.

"There is one infallible guide for the correct projection of lines to be deviated from only for very good reasons.

"Following that route which affords the easiest possible grades for the longest possible distances, using to that end such amounts of distance, curvature and rise-and-fall as may be necessary, and then pass over the intervening distances on such grades as are then found necessary. But when the higher grades are in danger of exceeding 1 in 50 (2%) or 1 in 40 (2½%) the rule is only to be accepted with great caution; as a line falls below 100 miles in length the economy of using pusher grades decreases and the practical advantage of a uniform grade increases."

"How to project low grades, how to project pusher grades, pusher grades on easy gradients, long pushers on heavy gradients,"

all these matters receive thorough treatment by Wellington and should be studied from his book. Much of the argument is in connection with lines of considerable traffic. One point, however, to be well noted is the importance of getting easy gradients over low ridges in a generally flat country, such as our Mallee country. (= Prairie.)

"Expedients for reducing the rate and cost of high grades," all this should be carefully studied and re-studied by the engineer when he is actually engaged in projecting lines in rough country.

The methods Wellington recommends for consideration are:

(1) "Hunt for some place on any part of the ascent where, for half its total length or more, a fairly good and cheap line may lie, in spite of surrounding difficulties, FIND WHAT RATE OF GRADE WILL FIT THIS SECTION AND WORK EACH WAY FROM IT, instead of going always to the summit and working down—which is a good rule for small descents, but will often lead one far astray in long ones. In other words, find out what are or ought to be THE GOVERNING POINTS, which may or may not be the summit, and work from them. In running a first rough preliminary it is ordinarily best to start from the summit, but on a second line it is rather the rule than the exception that it should not be done."

Some interesting examples and illustrations of the application of this principle are given on pp. 676 and 677.

(2) Zigzag Developments.—He means by this, grade developments by finding favorable points for the line to turn a half-circle or so and return on itself. See his illustrations p. 679. What are known as zigzags here and in New South Wales, Wellington calls "switch-backs."

(3) Spirals, or a doubling back of the line upon itself so that it returns under itself at a lower elevation. There are two classes, Bridge Spirals and Tunnel Spirals. See Figs. 210 and 211, p. 679.

(4) Included above.

(5) Switch-backs, the proper way of laying out which are given in Appendix C. Wellington favors the use of switch-backs more freely than they are used, preferring them to zigzags, or spirals, as the switch-backs are generally cheaper in construction and save much curvature.

(6) Inclined planes and cable traction. This matter is treated and examples quoted.

(7) The Rack Railway.—Abt and the Fell System. The Abt System may be seen on the Mt. Lyell Railway in Tasmania, and the Fell may be seen in the North Island of New Zealand.

Par. 944, "But after all, a plain descent from a summit to the plain below will ever remain the normal type for location, etc."

A description is given of the various great inclines of the world.

Part IV.—Larger Economic Problems.

CHAPTER XXI. — TRUNK LINES AND BRANCH LINES.

Trunk Lines.—This matter is dealt with mostly in view of competitive traffic. Par. 965 gives a rule applying to railway extension in this State.

Link together the largest population, regardless of minor losses of distance, provided the aggregate population per mile of road is not diminished (see par. 237) or even sometimes if it is.

Branch Lines.—Paragraph 982 says: "The reason for the continued and rapid building of branches in spite of their apparent unproductiveness is simply this: They contribute traffic to the main line which, as it is merely an increment, costs always comparatively little to move and often nothing at all!'" Par. 984, "The one universal rule, to be departed from only when special reasons to the contrary appear, is this: '*Strike the main line as soon as possible*'." Par. 986, "To the preceding is to be added another still more important rule: '*Strike the main line at a considerable town, if possible*'."

All this part in relation to branch lines should be thoroughly studied as it particularly applies to our railway extension problems, the main lines being practically complete.

CHAPTER XXII.—LIGHT RAILS AND LIGHT RAILWAYS.

Wellington argues against the using of light rails and the cutting down of the roadbed in the attempt to secure economy. He concludes:

(1) "As respects the minor details, distance, curvature, and rise-and-fall, their effects to increase expenses are at best small, and when the traffic is very light become very small. They are, therefore, one of the first directions in which close economy is warrantable for very light roads.

(2) "In a less degree the same is true of ruling gradients. Much increase of expenditure to obtain lower grades than a careful study of the ground shows to be possible at a minimum expense is not warrantable.

(3) "Both the above conclusions are especially true when the objectionable details may be readily corrected later, when and if the traffic warrants it.

(4) "Temporary wooden structures to decrease the immediate outlay are the next most judicious direction for economy.

(5) "Economies which decrease the stability of the permanent way are the most objectionable of all.

(6) "Sources of local traffic which can be reached by any reasonable sacrifice should in no case be neglected."

The whole of this chapter applies to the conditions prevailing in Victoria. On some of our recently constructed lines the cutting down of the formation width to 13 ft. 3 ins. and the length of sleepers from 9 ft. to 8 ft. can hardly be classed as economy. From 16 to 18 ft. should be the minimum width for the roadbed if proper drainage and cheapness of maintenance are desired. Also see Par. 1044, "One of the very worst places to economize in, is in the cross ties" (sleepers).

Wellington's arguments against the narrow gage are generally against the gages between 3 and 4 ft. wide, used on lines with a fair amount of traffic, and likely to be connected at more than one point with the standard gage. They will not apply so strongly here owing to the difference in the class of rolling stock in general use on our lines from the American types, also because of the more rapid increase of population in America.

Recently the 2-ft. 6-in. gage has been adopted in three branch lines in Victoria.

In considering the gage to be adopted, separate estimates of cost and traffic for both gages should be made, taking care to allow full estimates for rolling stock on the narrow gage. The cost of transfer of goods should be capitalized and added to cost of the narrow gage. In estimating the tonnage of goods in either case, allowance should be made for future development, say in five or ten years' time. The greater the traffic the less favorable will the narrow gage appear.

Other considerations will come in, in deciding the gage, such as future extension or probable connection with the standard gage at some other point.

The gage question is finally settled by Parliament in each individual case, but it is the duty of the engineer to look at the question from every point of view and to reduce the pros and cons to as definite lines as possible from a financial point of view and in view of the future development of the country.

In some cases it has been "narrow gage or nothing," on account of the estimated extra cost of the standard gage. In many districts a single-rail railway (no gage) would be preferable to leaving the country unsettled and undeveloped.

CHAPTER XXIII.—ECONOMY OF CONSTRUCTION.

The whole of this chapter should be carefully studied as it applies in every detail to conditions prevailing in Victoria, in fact, to railway location anywhere. The bad practice of cutting down the roadbed for supposed economy is again emphasized.

CHAPTER XXIV.—THE IMPROVEMENT OF OLD LINES.

This chapter deals chiefly with improvements of gradients and is well worth study, though it does not apply to location of new lines.

CHAPTER XXV.—GRADE CROSSINGS AND INTERLOCKING.

This chapter deals with the crossing of one railway by another at grade level and the legal rights of private companies in respect thereto, also with methods of interlocking to reduce the danger and expense of grade crossings.

Chapter XXVI., on Terminals, does not apply to the question of railway extension in Victoria.

Part V.—The Conduct of Locations.

The whole of this Part V applies, in every detail, to the location of new railways anywhere. In fact it presents the only true methods and principles which should guide the locating engineer. Any man who starts out on surveys without having made a thorough study of this portion of Wellington may be certain of falling into serious errors of location. It would be just as sensible for a doctor to start operating who had not studied anatomy or for anyone to attempt to design a bridge, who had not studied mechanics and the strength of materials. For railway location, properly studied, can be reduced to as an exact science as surgery or structural engineering. In every business assumptions have to be made, but it is the business man's duty to base his assumptions on reasonable data and to act on them consistently.

CHAPTER XXVII.—THE ART OF RECONNAISSANCE.

Wellington's conclusions are:

(1) "The reconnaissance must not be of a line but of an area.

(2) "All prepossessions in favor of any particular line

must be abandoned, especially in favor of the line which appears most obvious.

(3) "A tendency to see with undue clearness the merits of lines lying close to highways or the more settled or open districts must be carefully guarded against.

(4) "Lines hard to get over on foot, or overgrown with timber or tangled undergrowth, seem infinitely worse by comparison than they really are, and

(5) "Raggedness of detail, sharp rocky points, steep bluffs and the like exert an entirely undue influence on the mind as compared with long rolling slopes spread out over a longer distance.

(6) "A full mental map of the water courses should be made as the reconnaissance proceeds.

(7) "False summits or those which do not really divide two watersheds are very liable to deceive.

(8) "The engineer should make it a rule to invariably discredit all unfavorable reports from whatever source derived, which do not accord with what he expects."

CHAPTER XXVIII.—OCULAR ILLUSIONS.

This chapter demonstrates the importance of not guessing at things by a mere distant view, but of actually travelling to and noting all controlling points under reconnaissance.

CHAPTER XXIX.—WHEN TO MAKE SURVEYS.

This chapter argues that surveys should not be started until the reconnaissance of the area has been thoroughly completed. This matter has been dealt with in the first part of this paper.

CHAPTER XXX.—THE FIELD WORK OF SURVEYS.

The method given cannot be improved in practice and should be adopted entirely. The details cannot be better described than by Wellington. (1) The exploration line; (2) First preliminary; (3) Second preliminary; (4) First location; (5) Final location. All these processes are to be gone through in rough country, but will be reduced as the country becomes easier.

CHAPTER XXXI.—TOPOGRAPHY; ITS USES AND ABUSES.

This chapter should be well studied and restudied when the engineer is actually on the survey. Bear in mind that the topography should be based on a fairly well located line, and that it should be only sufficiently wide and sufficiently accurate to ensure the best final location as to the minor details of curvature and distance. The questions of rise and fall and of the larger differences in distance will have been settled before it becomes necessary to start the final topography. Though a section (or profile) plotted from a contour plan may be several feet out in odd places (as it often may be in rugged places) yet its utility is not impaired, for the position of the curves, as fixed by the general run of the contours, will be in the desired places and, as to estimates of earthworks, etc., the errors of topography will give and take. In fairly straight side-hill work the contour plan should always be (and will generally be found to be) accurate enough to fix the line at the proper elevation. At places where there are a succession of cuttings and banks great accurary in detail is not important. It follows that the topography may be taken with degrees of accuracy varying with the importance of getting the alinement within definite *vertical* limits. Before starting to do the contouring a list of chainages should be made out showing how much topography is required. In steep country the contouring should be taken just far enough to enable the *grade* contour to be plotted on the plan; where the slopes are flatter the contouring should be taken to the limits of possible curvature; in all cases to be taken far enough to enable one to estimate the line of minimum *economical* curvature. It is an easy matter to extend the contouring at special places after it is found necessary, but the time spent in taking wide belts of unnecessary topography is absolutely wasted.

Note Par. 1231, "The topography based on slope notes, by whatever method taken, *should invariably be drawn in the field* directly upon the working maps of the line." In general practice it will be found sufficiently accurate to take slopes with a clinometer using a tape for the distances where necessary. The Watkins (pendulum) clinometer is the handiest for taking side-slopes.

In rough country (on permanent surveys) the contours should be taken by using a hand level (Abney) fixed on a five-foot stick in conjunction with a tape and a ten-foot stick held by the staffman. Then the actual horizontal distance for each five-foot difference in level is measured directly on the ground and immediately transferred to the working plan.

If it is impracticable to use plans in the field, owing to dense undergrowth in a wet season, the contours should be plotted in camp by the man who takes the observations and as soon as possible thereafter. It is always best for the man who is responsible for the detail location to personally take the topography as he thereby becomes more intimate with the country, noting places liable to landslips or with rock on surface and other details affecting location. In all cases be sure that there is good reason for not plotting the topography in the field if not so taken and that laziness is not the deciding factor.

As to the scales to be used for the contour plans 4 chs. to the inch (264 ft. = 1 in.) with contours every 10 ft., should be the smallest—for undulating country requiring curves not sharper than, say, 12 chs. radius (7° for 100 ft. chord); 2 chains to the inch (132 ft. = 1 in.) with contours every 10 ft. for fairly difficult country requiring the use of curves of 5 chains radius (16½°) and 1 chain to the inch (66 ft. = 1 in.) with contours every 5 ft. for rough country requiring the use of curves sharper than 5 chains radius and for all narrow gage lines; also for specially critical places in country requiring, generally, the use only of the smaller scales.

In the roughest country the location will be finally fixed by the use of cross sections in conjunction with large scale contour plans as described in Par. 1197.

CHAPTER XXXII.—MAPPING AND PROJECTING LOCATION.

Wellington advises the use of small sheets 19 × 24 ins., or 19 × 36 ins.

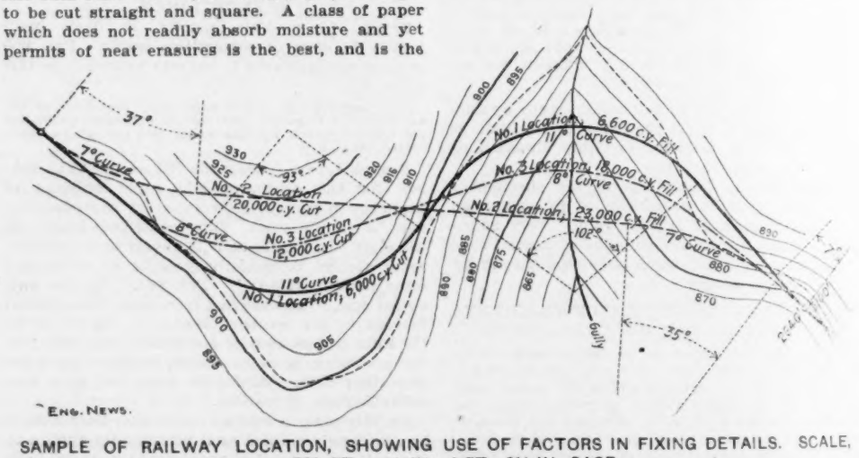
I find that hand-made foolscap sheets about 26 × 17 ins. are the most suitable, being lighter and of less bulk than ordinary drawing paper, the edges to be cut straight and square. A class of paper which does not readily absorb moisture and yet permits of neat erasures is the best, and is the better for being slightly tinted, so as not to try the eyes.

In taking topography in the field, as many sheets as are required for the day may be fixed on a light board with rubber bands, the board being held by shoulder straps, so that it may project at a suitable height for drawing on and may lie under the arm when not in use.

The location should be projected on the sheets exactly as described by Wellington. Reverse curves plotted on tracing cloth, with the minimum length of straight between, should be used for fixing the location. A table should be prepared showing the distance to fall one contour for various curves consistent with the adopted ruling grade for straight. (See illustrations.)

It is now that the use of the factors for minor differences of curvature and distance come in for finally fixing the location. The first line projected on *paper* should be that of *least construction* cost, then try another line or two with *less* curvature. The cost of these alternative lines can be estimated without plotting the profile, by reading off the depths of cuttings or banks from the plotted grade contour on the plan. The curvature can be scaled with a small transparent protractor to the nearest degree or so.

To fix final location, tabulate the estimates of the alternative lines, bit by bit, adding the capitalized cost of differences in minor details to each line. It will be found that the total capitalized cost of a line lying somewhere between the line of maximum curvature and a line run fairly straight will be the *minimum* and that within certain horizontal limits, to right or left, the *total capitalized* cost of any line will be the same as this minimum, i. e., within a certain area on the plan there may be several lines of which the construction cost added to the capitalized cost of minor details will add up to the same figure. This may be called the "area of economical location." The position of this



SAMPLE OF RAILWAY LOCATION, SHOWING USE OF FACTORS IN FIXING DETAILS. SCALE, 500 FT. = 1 IN., 4-FT., 8½-IN. GAGE.

NOTE.—Colors used on working plans:
Contour lines.....Brown (every fifth line thicker)
Grade line.....Dotted blue
Location lines.....Black, red and green
Watercourses.....Blue

ESTIMATES:

NO. 2 LOCATION.

Length, 2,640 ft.	Curvature, 72°.	
Cwt...20,000 cu.yds.	at 40 cts.	$8,000
Filling 3,000 "	at 25 "	750
Culvert		570
Ballast, ties and rails		4,000
Construction cost		$13,320

NO. 3 LOCATION.

Length, 2,840 ft.	Curvature, 122°.	
.....12,000 cu.yds.	at 38 cts.	$4,560
..... 6,000 "	at 25 "	1,500
Culvert		425
Ballast, ties and rails		4,300
Extra curving, say		100
Construction cost		$10,885
Addt'l curvature 50°	at $30..	1,500
Additional distance 200'	at $3	600
		$12,985

NO. 1 LOCATION.

Length, 3,100 ft.	Curvature, 202°.	
.....7,400 cu. yds.	at 36 cts.	$2,664
..... 300 "	at 25 "	75
Culvert		250
Ballast, ties and rails		4,700
Check railing, etc.		640
Construction cost		$8,329
Addt'l curvature 130°	at $30..	3,900
Additional distance, 460'	at $3	1,380
		$13,609

Assumed Traffic, Three Daily Trains.

NOTE.—Thus for an assumed traffic of 3 daily trains, these three locations capitalize to about the same total figure.

(1) If this amount of traffic is assured from the startand is likely to increase, it would pay to adopt No. 2 location.

(2) If traffic will start at 30 daily trains and remain constant No. 3 location would be suitable.

(3) But if the traffic is expected to be small at first, but to gradually increase to 3 trains per day, No. 1 location should be adopted, as being cheapest in first cost and also economical for the expected traffic.

Assuming a Traffic of Two Daily Trains.

	No. 1 Location.	No. 2 Location.	No. 3 Location.
Construction cost	$8,329	$13,320	$10,885
Additional curvature	2,600	.....	1,000
Additional distance	920	.....	400
	$11,849	$13,320	$12,285

Thus for an assumed traffic of two daily trains No. 1 Location would be the most economical (though No. 3 capitalizes very little higher). The area between Nos. 1 and 3 locations would be "the area of economical location."

area will depend upon the greater or less values which have been fixed for the minor details. Generally adopt that one of these lines with the least cost for construction. This line will always cost somewhat more than the line of maximum curvature, but will require very much less curvature.

The question of adopting the line of least construction cost within the "area of economical location" will depend upon how the factors for the minor details have been fixed. (1) If the factors have been based on the ultimate developed traffic—then take the line of least construction cost, i. e., introduce curvature at *these valuations* to save construction cost; (2) but if the factors have been based on the traffic expected in the immediate future—then take the line with least curvature (within the "area of economical location"), i. e., introduce increased construction cost to lessen curvature, at these valuations. Either method will give approximately the same final location.

In rough country the variation in cost between lines on the outside limits of the "area of economical location" will, in some cases, amount to a large figure, even up to £1,000 ($5,000) per mile, when the factors for minor details have been based on the first method.

All this may seem elaborate, but it will only require to be done where there may be reverse curves. Then each pair of curves will be a separate problem, as shown on illustrations.

In cases of isolated curves, sharp radii should not be adopted without estimating also the cost of some easier curve, not forgetting to take into account the cost of guard-railing. On the 5 ft. 3 in. gage all curves of 8 chains radius (11°) and sharper are guard-railed and similarly 4 chain curves (22°) and sharper on the 2 ft. 6 in. gage.

In projecting pioneer lines with much curvature, always consider the possibility of the line having to be straightened for future development of traffic, and allow for this in the grade, i. e., run slack grade where the length has been increased for the purpose of cheapening first cost. This applies more particularly to the location of narrow gage lines which, at some future time, will probably be converted to standard gage.

In comparing timber structures with earthwork, take timber work at a high estimate to allow for renewal and for risk of fire, say 50% over actual cost. In steep rocky country estimate the culverts as being put in near the end of the bank and the hollow filled up, but be sure that springs of water on the seat of the bank are provided for and that there is a good inlet to the culvert. Test the country for rock before starting to fix final location.

The important thing in location is to have the alinement consistent throughout with the factors adopted—not omitting to apply them in some cases and applying them in others by mere caprice.

If the cost of the line has been fixed by a previous trial survey and the money voted is limited, run a location through, then adopt factors to suit the available money, *or* adopt the standard factors (consistent with the traffic) generally throughout the line and save your money at some isolated points by introducing temporary deviations. The latter method is preferable, but the opportunity does not always present itself.

After the final location is fixed, write on the plans the various estimates used in fixing the alinement so that a permanent record may be preserved.

The contours should be adjusted to agree with the levelled section (profile) of the adopted line.

SOME HINTS AS TO THE MANAGEMENT OF A SURVEY PARTY.

Try to get your men interested in the work, especially the subordinate officers. If the work is conducted in a methodical, common-sense manner, they will generally take a keen interest in the survey, and the work they are entrusted with will show the benefit. Don't do one sort of thing to-day and another to-morrow, and worry about, all over the line, but carry forward the work from the beginning to the end of the line methodically, and *don't start pegging* the located line until it is fixed for the whole section of the survey and until you are absolutely satisfied with it. It is always a bad sign—a sign of weakness—when a man has to pull up his pegs.

Even after the location is apparently fixed, it is better to put the men on other work, such as property and descriptive survey, so that you may have time to give the location further quiet study, to compute quantities, plot cross sections, etc.

By the "descriptive survey" is meant the surveys in connections with the land to be taken for the railway, involving the picking up of the old surveys of properties.

In doing the descriptive survey in heavily timbered country, it is easiest to follow up old survey lines with a compass, get a traverse cleared and chained, then pick up the bearings with the theodolite: compute closing lines and put in pegs on the true allotment lines on either side of the railway center line for getting connections with the railway fence lines.

Also in running fence lines, have as few angles as possible; don't slavishly follow parallel to the center line where there is much curvature; you can often run a straight line past several curves. When the fence lines are not to be parallel to the center line, they need not be computed beforehand; but, having fixed their approximate required positions on the large-scale plans, lay them out with the compass, getting the lines to clear the trees as much as possible, approximately at the required distance from center line. Get these lines cleared and chained, then come out with your theodolite and complete the survey.

Make the life as pleasant as possible for your men. See that they are well fed and that their health keeps good. If green vegetables are not to be had, get dried or preserved articles.

Before going far from civilization, get a full and complete supply of all necessary stores to last for two or three months, at least a full load for a wagon so that the cartage will not be too expensive. It is the practice here to charge the men, when being paid monthly, for the amount of stores used during the period.

Encourage the men to go in for rational amusements during the evenings, but discourage gambling games of any sort: they generally lead to rows.

Men, otherwise capable, who foment trouble or disloyalty are best out of a survey camp.

Study "First aid to the injured," and keep your medicine chest up to date.

CHAPTER XXXIII.—THE ESTIMATION OF QUANTITIES.

This chapter argues that extreme precision is not necessary in estimating quantities for location.

The necessary tables of earthworks are all in print, giving cubic yards per chain for depths for 1 to 60 ft., and for slopes 1½, 1, and ¾ to 1. For computing the contents on sloping ground, a table of percentages to be added is used. The above tables are all that are necessary for computing earthworks for trial surveys.

For permanent surveys the final quantities are taken out from tables of end areas, mean area method, corrected by a table of deductions for the prismoidal formula. Plotted cross sections are used where the country is rugged but where the side slopes are fairly straight the table of added percentages is used.

Culverts. A table of the quantities for all the standard culverts is used. The number and length of each size of culverts is tabulated and multiplied by the respective constants per number an per lin. yard.

Bridges. Timber bridges of standard designs are used on all new country lines. Estimates of cost per lin. foot for varying heights are made out for each type of bridge, prices (per cubic foot of beams and per lin. foot of piles) varying according to locality. Lists of the bridges are made out showing total length of each type at heights varying by about ten foot.

Separate estimates are made of large bridges of special design.

This ends the last chapter of Wellington's book.

Whatever opinion may be formed as to the value of this paper, if the perusal of it will encourage the study of Wellington's book and of articles on Railway Location in current periodicals, the result will be good.

As to engineering periodicals, my opinion is that those which give useful practical information on matters of ordinary and everyday practice are much more valuable than some which deal only with abnormal and extraordinary matter.

Appendix A. Experiments on the resistance of rolling-stock.

Appendix B. Experiments with new apparatus on journal friction at low velocities.

The results recorded are utilized in arriving at conclusions in the body of the work.

Appendix C. The American line from Vera Cruz to the City of Mexico, via Jalapa, with notes of the best methods as surmounting high elevations by rail.

His reasoning is sound, so the matter cannot be better studied than by reading the original.

RULING GRADES.

Example 1.—Working out a sample case from Wellington's Table 178, assume a line 30 miles long—ruling grade 1 in 100—2 daily trains. What is the capitalized value of increasing the ruling grade to 1 in 75?

1 in 100 = 1%;
1 in 75 = 1.33%

See table 178.
Increase of grade 1.0 to 1.2% = $2,530 × 2.0 = $5,060
Increase of grade 1.2 to 1.33% = 2,277 × 1.3 = 2,960

Per daily train per year for section of 100 miles..$8,020 or £1,600.
£3,200 for 2 daily trains for a section of 100 miles.
960 for 2 daily trains for a section of 30 miles.
Capitalized at 4% = £24,000 (working expenses, 50d or $1 per train-mile).

Example 2.—A line 30 miles long—ruling grade 1 in 40—2 daily trains. What is the capitalized value of increasing the ruling grade to 1 in 33.

1 in 40 = 2.5%.
1 in 33 = 3.0%.

See table 178.
Increase of grade, 2.5 to 2.6%..... = $1,590
" " " 2.6 " 2.8%..... = 3,036
" " " 2.8 " 3.0%..... = 2,880

Per daily train per year for section of 100 miles $7,516 or £1,500.
£3,000 per year, 2 daily trains, section 100 miles long;
900 per year, 2 daily trains, section 30 miles long.
Capitalized at 4% = £22,500 (working expenses 50d. or $1 per train-mile).

This method only applies when the heaviest available engines are required for easy grade, also the capitalized value will vary with the proportion of time per year during which there would be full loads.

On a recently constructed line, 23 miles long, £15,000 ($75,000) was spent to reduce the ruling grade from 1 in 25 (4%) to 1 in 40 (2½%)—a wise expenditure.

On another line £8,000 ($40,000) was saved by increasing the grade from 1 in 37½ (2.7%) to 1 in 30 (3.33%) where the line was not against the loaded trains, the ruling grade for loaded trains being elsewhere 1 in 37½ (2.7%), also a justifiable course.

TRANSITION CURVES.

The spiral curve is the generally accepted form. It is useless to go into a lot of abstruse mathematics as to whether this is the correct theoretical method. Any method of putting in transition curves requires that the body of the curve shall be shifted some distance towards the center. The length of the transition curve should be the length in which the superelevation of the outer rail increases from nothing to its full amount. This length is indeterminate by theory but varies in practice from 99 ft. to 264 ft. The higher the speed, the longer the transition curve needed.

Transition curves cost nothing when laid out on the original survey and have no determinate economical value in working expenses. They certainly obviate shock to rolling stock and to passengers and lessen the necessity for slowing up when entering curves—all desirable objects.

In a spiral curve consisting of a number of short circular curves of diminishing radii, the amount of curvature is proportional to the length.

The total curvature is $1 + 2 + 3 + n$.

Dist. and curvatures	1	2	3	4	5	6	7	8	9	10	11	12
Total curvatures ..	1	3	6	10	15	21	28	36	45	55	66	78
Offsets	1	5	14	30	55	91	140	204	285	385	506	650

First Example.—Curve 10 chains radius, spiral 100 ft. long, in four circular arcs 25 ft. long of diminishing radius.

The angle subtended by 25 ft. of the curve 660 ft. radius is $\frac{25}{660} = 0.038 = 2° 10'$.

The curvature in the first arc of the spiral will be one-fifth of this, 0° 26'.

The total curvature of the spiral will be 26' × 10 = 4° 20'.

1st offset..... = 25' × sin ½ (26') = 0.0945 ft.
2d " ..... = .0945 × 5 = .4725 "
3d " ..... = .0945 × 14 = 1.32 "
4th " ..... = .0945 × 30 = 2.835 "

Distance of tangent from circle = twice middle offset of spiral = .945'.

Second Example.—Curve 10 chains radius, distance of tangent from circle 1 ft. 6 ins. Join circle to tangent with a spiral in four arcs.

$$2d \text{ offset} = \frac{1.5}{2} = .75 \text{ ft.}$$

$$1st \text{ offset} = \frac{.75}{5} = .15 \text{ ft.}$$

3d offset = .15 × 14 = 2.10 ft.
4th offset = .15 × 30 = 4.50 ft.
Radius of 1st arc = 660 × 5 = 3,300 ft.
Length of arc = square root of (2 × 3,300 ft. × .15) = 31 ft. 6 ins.
Total length of spiral = 31 ft. 6 ins. × 4 = 126 ft.

GRADING RAILWAY SECTIONS.

(Some General Hints Based on Actual Observed Errors.)

No sags in cuttings—no summits on bank.

Easy grade out of stations for loaded trains (attend to this in location).

Don't bring summit of grades right up to surface—always allow enough cutting to balance, saving in rise-and-fall. Similarly in banks with sags.

Avoid long shallow cuts, especially on level. This does not apply to side-hill cuts. See to this in location.

Generally allow excess of bank in undulating country—say one-third of bank to be made from side-cutting. This, of course, depends upon length of lead and the sort of stuff to be shifted. Treat special cases in detail by trying parallel alternative grades and pricing materials according to local circumstances.

Balance earthworks so that cuttings will be absorbed by the adjacent banks, if possible, so as to avoid long lead. This should be seen to in location.

Avoid continuous side-cutting liable to become scouring watercourses.

Balance earthworks for stuff in station grounds and fix grade accordingly, not merely for banks and cuts in center line.

In mountain lines with steep side slopes grading must be done from cross-sections—safety of line is more important than balancing banks and cuts.

The grading should be fixed by the location engineer on the ground.

Avoid level crossings on steep grades and near sharp curves. Safety and economy of working are more important than trifling savings in first cost.

In starting to grade an undulating section, don't go for long grades at first; similarly as recommended in location of horizontal curves, grade as cheaply as possible at first, then improve by knocking trifling changes of grade, considering capitalized value of rise-and-fall.

Don't expect to get the final grading first shot. Take out the quantities, then go over the section, bit by bit, and see if you can lessen earthwork or improve grade, always remembering that the latter is the most important.

Don't be surprised if the whole of the first grading has to be altered.

Compare the savings made by additional care with the value of your time; then you will see that thoroughness always pays. Don't be afraid of detail if the result is determinate.

The general principle of grading is to have sags in the part of the bank where they will save most and similarly summits of grade in cuttings.

The undulations of grade will be limited by the vertical curves and the amount of "straight grade" allowable between. In adopting vertical curves, don't use the sharpest allowable curve unnecessarily. It is not necessary to use a uniform curve throughout the whole line. Vertical curves in sags, whatever the change of grade may be, must be over the train length—say not less than 6 chains (= 396 ft.) anywhere. The proper length of the vertical curve will depend on two considerations (1) avoidance of dangerous jerks (2) saving in rise and fall.

The theory of "jerks" is to some extent indeterminate, depending on the use of the brakes, whether steam is on or off and the proximity of sags and summits.

On old lines it is known by experience where jerks occur and to what extent vertical curves are required. These places are mostly the result of the original bad grading. It is the generally accepted theory that jerks will occur at a sag where two long grades meet too sharply but will not occur on the summit of two long grades. It follows that the proper method of arriving at the length of vertical curve on summits is to estimate what various lengths of curve will cost and to capitalize the rise and fall saved and for sags to compute what length of curve will reduce jerks to a safe limit, but to adopt an easier curve if the saving in rise and fall justify it. At minor changes of grade the cost of vertical curves will be so small that there is no reason for making them sharper than those fixed by economical reasons, where they can be so fixed.

Don't spoil the length of straight grade at stations by using unnecessary vertical curves. They are not required at stations.

In grading flat lines, keep formation well above ground so as to avoid soakage of moisture from the natural surface up to the ballast—say at least a foot of bank, but if the grade is fairly steep the formation should not be lower than enough to take the stuff from the ditches—say 6 ins.

In minor changes of grade, don't put in vertical curves if a length of straight grade (say over 6 chains) will cost no more, and will allow efficient drainage.

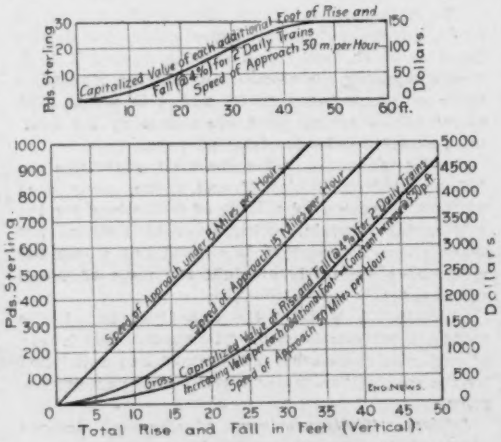
The following table shows the economical rates of change for vertical curves at ordinary cost of earthworks—for traffic of two daily trains and of four daily trains.

Ruling grade	1 in 75, or 1.33%.	1 in 50, or 2%.	1 in 40, or 2½%.	1 in 30, or 3.33%
Rates of change per chain (66 ft.).				
Depth, cut or bank, without vert. curve	Daily trains 2	4	2	4	2	4	2	4
10 ft.	.10	.10	.15	.10	.20	.15	.22	.15
20 "	.20	.12	.25	.15	.35	.25	.40	.25
30 "	.28	.15	.35	.20	.50	.35	.70	.40
40 "	.37	.19	.45	.25	.65	.45	1.00	.50
50 "	.44	.22	.55	.30	.80	.55	1.40	.62
Sharpest vertical curve in sags....	.11		.22		.33		.50	
Length at junction of ruling grades.	.16 chns = 1,056 ft.		11 chns = 726 ft.		10 chns = 660 ft.		8 chns. = 528 ft	

The accompanying diagrams show the method by which the above table has been compiled.

Straight grade between reverse vertical curves.

There is no determinate economic limit for the minimum length of straight grade between reverse vertical curves but the following minimum distances from center of summit to center of sag may be generally adopted and should be provided for in location.


Rds Sterling
Dollars
Capitalized Value of each additional Foot of Rise and Fall (at 4%) for 2 Daily Trains
Speed of Approach 30 m. per Hour
Pds. Sterling
Speed of Approach under 8 Miles per Hour
Speed of Approach 15 Miles per Hour
Speed of Approach 30 Miles per Hour
Gross Capitalized Value of Rise and Fall (at 4%) for 2 Daily Trains
Increasing Value per each additional Foot
Constant Increase $50 ft
ENG. NEWS.
Total Rise and Fall in Feet (Vertical).

Diagrams Showing Cost of Vertical Curves Compared with Saving In Rise and Fall.

Additional Earthworks for Vertical Curves at Intersection of Two 1 in 40 grades. Formation width 15 ft. 6 ins.

Curve const.*..	.41	.33	.275	.20	Added percentage
Length	8 chains 528'.	10 chains 660'.	12 chains 792'.	16 chains 1,056'.	for banks, 1½ to 1 batters.
Height saved ..	1.67'.	2.46'.	3.30'.	4.94'.	
Depth of cutting:†	yds.	yds.	yds.	yds.	
5 ft.....	490	788	1,213	2,378	24%
10 ".....	668	1,100	1,676	3,138	29
15 ".....	846	1,412	2,139	3,958	33
20 ".....	1,026	1,724	2,602	4,800	36
25 ".....	1,206	2,023	3,065	5,680	37½
30 ".....	1,390	2,322	3,528	6,500	39
40 ".....	1,748	2,920	4,460	8,154	42
50 ".....	2,108	3,520	5,385	9,810	44
	Extra earthwork in cutting, 1 to 1 batters.				

*Per 66 ft.
†Without vertical curve.

1 in 75 ruling grade	(1.33%)	24 chains	(= 1,584 ft.)
1 in 50 "	(2%)	17 "	(= 1,122 ")
1 in 40 "	(2½%)	15 "	(= 990 ")
1 in 30 "	(3⅓%)	12 "	(= 792 ")

FIELD WORK.

General order of procedure in location of lines in hilly and mountainous country:

(1) Settle controlling points, such as stations, river crossings, avoidance of dangerous flooded areas, and saddles which will control the grade.

(2) Run shortest preliminary lines between controlling points. These will be mostly grade lines run with the clinometer. Run alternatives where required, i. e., where there exists in your own mind (or is likely to exist in the mind of any other engineer) any doubt that the shortest is the best and has the least curvature. Traverse the grade lines with compass and chain, numbering the angle pickets in consecutive order (alternative lines being marked 1A, 2A, etc.), leaving indicators at each station for the leveller.

(3) Take a set of levels along the traverse, leaving depths of gullies to be picked with the clinometer when afterwards doing the topography.

(4) Having plotted the traverse and written the reduced levels on the working plan, contour the traverse in the field (lines in pencil).

(5) Locate the line on the plans.

(6) Locate the line on the ground (i. e., the adopted line, alternatives being estimated from the contour plans) taking the working plans with you in case of errors in plotting; also take a few curve rulers and a small protractor in case of alterations being required.

(7) Take the section. The side slopes can be taken from the contour plans.

(8) Do the necessary marking on the ground, pegging, blazing, etc.

(9) Get connections with existing property surveys and plot plan and section.

The plan is best plotted by scaling the latitude and departure of each end of every curve from the large-scale plans.

This finishes the survey for trial lines as far as the location is concerned.

During the survey and previous reconnaissance, notes will have been made as to character of country, waterways, etc.

For final location of permanent survey proceed as described under the head of "Mapping and Projecting Location."

NOTES FOR DRAFTSMAN, PLOTTING LOCATION PLANS.

(1) Fix North Point on plan and connecting marks with previous sheet.

(2) Plot grade traverse, putting title and scale on plan, ink-in and number angles.

(3) Write in pencil the chainages every 5 chains and the reduced levels of transverse.

(4) After the contours have been pencilled on, don't ink them in if the line is to be located on the ground and actual section to be taken.

(5) After the line has been located on the ground, check the chainage with the connections that have been taken with the traverse, and see that there are no serious differences between the plotted traverse and the located line.

(6) After adjusting differences ink-in the located line.

(7) Write on in pencil the reduced levels of located line and adjust the contours to agree with the levelled section.

(8) Ink-in the corrected contours (brown) making every fifth line thicker and inking in the levels of the contours at convenient points first.

(9) After the section has been finally graded, adjust the grade line on the contour plans and ink it in (dotted blue).

(10) Mark centers and directions of gullies in blue.

(11) Ink in Title, North Point, radii of curves, central angles at curves, allotment lines, fences, buildings, mileages of located line, showing through mileages at beginning of each sheet, ink in number of sheet.

(12) Clean up plans, get them signed by officer in charge.

(13) Before starting to ink-in the plans make out a list of the plan numbers and of what is required to be done, then check off each item as it is completed.